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CONTENTS

PEOPLES REPUBLIC OF CHINA

ABSTRACTS

PROBLEMS IN DEVELOPMENT OF SCIENCE OF MANAGING SCIENTIFIC RESEARCH OUTLINED

Beijing ZIRAN BIANZHENGFA TONGXUN [JOURNAL OF DIALECTICS OF NATURE] in Chinese No 6, 1981 pp 8-15

[Article by Li Chang [2621 2490], "Establishing and Developing in China the Science of Scientific Research Management"*]

[Text] In undertaking scientific management work, tasks are numerous and complicated. How can a good job of scientific management work be done? This very much merits diligent study. I believe that the most fundamental method is to make our management work more scientific, subjecting our scientific management to repeated analysis and synthesis, observation, and verification to gradually form a systematic, rational understanding that reflects the laws of scientific research management--the science of scientific research management. Below I raise several views on problems in the study and development of the science of scientific management.

I. Discussion of Problems in the Study of Scientific Research Management Methods

On the basis of the general principles of Marxism-Leninism and Mao Zedong Thought, taken together with the practical problems of our daily work, I have to understand that there are three major ways in which to study problems in scientific research management science.

1. Theory must relate to practice. This is the most fundamental method.

What is the theory of scientific research management? Our present theoretical concepts have mostly been introduced from abroad. They derive from two sources. One source is management science; the other source is metascience.

It is generally acknowledged that modern management science derives from a book written in 1911 by Taile [phonetic and possibly Tyler] titled, "Principles of Scientific Management." This book became the cornerstone of management science. Naturally, this is not to say that no management work existed before Taile, but rather that from this time onward, western management work had its own scientific theory. During World War II, owing to war needs, numerous scholars in the United Kingdom studied air defense strategy. In order to meet the challenge of German buzz bombs, in particular, scientists introduced operations science, using it to manage and deploy air defense weapons to effectively resist air

*Editor's Note: This is a portion of a report that Comrade Li Chang made on 20 August 1981 at the Chinese Academy of Science's Scientific Management Academic Discussion Meeting.

attacks on London by German V-2 guided missiles. After the war, operations science and systems science made giant strides in solving management problems in production and large research projects. Systems engineering is a new science that grew out of the use of systems science to solve engineering management and organizational implementation problems. Therefore, it is generally acknowledged that use of operations science and systems science in management work is the second stage in modern development of management science. The third stage of management science is the development in recent years of Japanese management work and management thinking. Japan emphasized the self-reliance of its people in a disadvantageous situation, attaching special importance to the work of staff and workers to combine scientific management with development of a dynamic spirit in staff and workers, linking the welfare of employees to the welfare of enterprises to attain an efficiency that is much greater than that of Europe or the United States. The "Matsushita spirit," or the "Toyota spirit" developed in Japanese enterprises are representative.

We should take a comprehensive look at modern western management science. Management science has developed out of a situation in which capitalism had entered the monopoly stage, the scale of enterprises and certain research engineering had become increasingly big and management work increasingly complex. On the one hand it has helped capitalists exploit the workers. As a result of the intensification of management, not only do the workers have to work at a hectic pace physically, but they have to work at a hectic pace mentally as well. Lenin made a brilliant exposition of this situation. On the other hand, it is scientific and it has a group of scientific theories and scientific methods, so management of all kinds of modern systems cannot do without it. For example, without this management science, American research and development of the atomic bomb, of nuclear submarines, and of the launching of the Apollo spaceship could not have succeeded. Therefore, we too should study management science. Only by relying on it can we do a good job in facing various huge and complex management tasks.

Metascience came into being in the late 1930's. Its creator was the renowned British scientist, Beierna [phonetic]. Beirna wrote many things, one of which was an important book titled, "The Social Function of Science." Publication of this book marked the birth of metascience. He also wrote two other metascience works: "Science and Society," and "Historical Science," the second of which has been published in Chinese. Following Beierna, and particularly since the 1960's, metascience has developed very rapidly abroad to become an academic field in which many noted students have appeared. Naturally western metascience also reflects the economic and social characteristics of various individual countries and carrys the imperialist stamp; consequently we should accept it only critically. For example, the west has a private ownership system and hires labor. Under a situation in which a small number of capitalists, particularly an extremely small number of monopoly capitalist blocs, controls the national pulse of the national economy and the people's livelihood, it practices free competition economically, but in fact only a small number of moneyed people fully enjoy bourgeois political and cultural democracy. The road and methods of western development of science under such social and political systems cannot all suit us. We must use them selectively.

These are the two aspects of theoretical concepts that we will introduce from abroad--management science and metascience. These are two specialized theories about which Marxism-Leninism and Mao Zedong Thought will have to give guidance, and which will have to be studied critically, taking their essence and discarding the dross for the gradual formation of our own management science and metascience and the building of our own theories.

Just what are the realities?

First, we are a large socialist country in the course of development. We have not yet industrialized, and we are relatively poor. In terms of per capita average output value, we stand beyond the hundredth position in the world. This is one aspect. The other aspect is that in terms of absolute output value, we stand among the first several positions in the world. In grain, steel, coal, and petroleum, we rank among the first 10. Therefore, our country differs very greatly from the west. Theirs is a post-industrial society. The total population in their third estate is more than the total population in the first and second estate. Western countries frequently term those who do mental work or service personnel (including hygiene, education and scientists and technicians) as "white collar," and those who do physical labor as "blue collars." We, however, are entirely different. Our physical laborers far exceed our mental laborers. This explains that our country's science and culture is still very backward. China is a large developing socialist country. This is the first reality.

Second, following the Third Plenary Session of the 11th Party Central Committee, China entered a stage dominated by socialist construction. After the socialist transformation of private ownership of the means of production was virtually complete, we still took class struggle as the key link, and this was a "leftist" error. Therefore the change that followed the Third Plenary Session possesses great strategic significance. At the same time China is now in a period of economic readjustment and restructuring, correcting the "leftist" errors in economic work that have endured for a long time, all the sectors of the national economy thereby being truly able to have planned proportional development. We are also beginning the practice of various forms of a system of economic responsibility to break the iron rice bowls and the egalitarian practice of eating out of a large common pot. Today readjustment and restructuring of agriculture has already won major breakthroughs. With the encouragement of the CCP Central Committee's correct policies, the broad masses of peasants' enthusiasm for production has had an unprecedented upsurge. Many places welcome scientists and technicians and have sent the "God of Wealth" packing to bring about a great turn of events in the several thousand year history of China's rural villages and agriculture. Readjustment and restructuring of industry will require an additional period of time. What problems does this demonstrate. This shows that in our building of the four modernization, we must rely first on policies and second on science and technology. We have to use modern science and technology for the technological reform of agriculture and industry to assure fulfillment of China's economic construction tasks. This is the second reality.

Third, China possesses a certain economic and scientific and technical foundation. Specialized scientific research organizations throughout the country today employ 33,000 research personnel, which is no small force. This is an

important circumstance. However, as to how we should employ this force to do a good job in our scientific endeavors is a matter about which we have no mature experiences and about which we have not formed our own models for development of science. The level of our management science undertakings is still very low, and large numbers of problems await our solution. Practice since the founding of the People's Republic and Central Committee documents have designated the Chinese Academy of Sciences as China's supreme academic organization and the overall research center for the natural sciences. Its research tasks include responsibility for basic science, technological science, and management science. We already possess a foundation for the first two of these, but research in management science has just begun. The purpose of this conference is to give impetus to research work of this nature. How to manage such a huge academic organization is a problem urgently awaiting research. In terms of the Chinese Academy of Sciences as a whole, not long ago, we made a major restructuring of the leadership organization, convened a conference of committee members in various fields, elected a body of chairmen, and from among the body of chairmen elected a director and deputy director of the academy, established five fields of learning and a management metascience unit, and firmed up academic leadership. Now that the main academy has been restructured, what to do about the institutes is a large problem that we must study and solve.

The three points given above are our current realities that are fairly closely related to scientific research. Theory must be linked to practice, meaning that it is necessary to use knowledge from the management science and metascience sphere to zero in on China's national scientific research work and problems to find management methods that are effective for us. Our point in emphasizing this is that we must be extremely careful in our use of foreign things. Circumstances in China differ greatly from those in foreign countries. Without clearheaded analysis, indiscriminate copying can often lead to losses. In the past we sustained losses as a result of indiscriminate copying of the methods of the USSR. Today we have to be sure not to suffer losses from indiscriminate copying of the methods of Europe, the United States, and Japan. We can only apply advanced foreign scientific theories in combination with practice in China, studying both overall macroscopic problems and studying the microscopic problems in each individual institute and unit, seeking in a combination of theory and practice ways to develop and effectively manage China's scientific endeavors. This is the first probelm in methodology.

2. Going from perceptual knowledge to rational knowledge, from the specific to the general, and from the general to the specific is another important method to which we should adhere. As applied to this academic conference, a difference exists between our explicit work report and academic report. It is sufficient for a work report to explain clearly specific circumstances and how problems were solved, but an academic report has to elevate to rational cognition, a knowledge of laws, or a knowledge of innate character. For example, in doing modern research, the Academy of Sciences has dealt with the problem of whether the Dongting Lake region should grow double crops of rice or a single crop of rice, and the problem of low yields per unit of area and inconsistent total output in Heilongjiang Province. These are external phenomena, but what is the innate character? Previous research slowly found some rational understanding. The innate character of growing crops is nothing more than a unified matter of biological factors and environmental factors. Grain crops are living things

that have their own laws of growth. The role of people has just two aspects: Use of its laws so that it fits the environmental factors, and change in environmental factors so they fit the laws of growth of crops, thereby unifying them to obtain more agricultural products for human use. Therefore, crops have to be compatible with soil, climate and such environmental factors, and this is a fundamental problem in agriculture. In perceiving the problem in this way, it is possible to see that some places in Taoyuan County in Hunan Province have an insufficiently long growing season for two crops of rice; consequently the late rice crop will not get sufficient sunlight, and energy and carbon dioxide will not be completely transformed into the organic matter of rice through photosynthesis; thus outputs will be very low. Therefore, double crops of rice will not work in some places in this province. To try to grow double crops of rice breaks the unity of biological factors and environmental factors, and wastes effort. The situation in northern Heilongjiang is as follows. First very little fertilizer is applied, so yields per unit of area are low. Secondly, the frost-free period there is short. It has been possible to grow wheat and soybeans there because wheat and soybeans are harvested early, and are suited to the climate there. Subsequently, in an effort to get high yields per unit of area from corn, much corn was planted and problems readily developed. Corn ripens fairly late. If the frost season arrives a few days early, yields will drop tremendously. Sometimes when the frost arrives just 1 day early, the whole province sustains losses of 100 million jin of grain creating inconsistency in total output.

In studying scientific research management problems, we should also use this method. We cannot simply study and solve them on the basis of problems in a single unit or a single institute. We must seek a general problem in the special problems of each institute, bringing it to an understanding of operative laws. In this way not only can the problems of these institutes be solved, but the problems of other institutes may be solved as well. To put it more simply, this method is simply to regard specific things as the rudiments, and then proceed to toss aside some specific phenomena to seek knowledge of the innate character, i.e. to elevate the particular to the general to bring forth some general concepts and cause these concepts not only to apply to a single unit but also to apply to other units. Once we have mastered these methods, we will have avoided the error of considering things as they stand, and give research work academic standards.

3. Summarization and creation from abundant practical experiences of scientific research the management theories that suit China's circumstances.

We comrades who study scientific research management problems have a common characteristic, namely that as a result of long work in scientific research management, we possess abundant practical experience. Our job is to summarize this abundant practical experience and create out of it our own theories. It was said in the foregoing that our present theories have been imported from abroad, and we must analyze, study, and master them; however, simple dependence on these theories is not enough. We must also have something that is our own. No matter how good someone else's things may be, they do not necessarily fit our circumstances. Only when those theories that have been demonstrated to be correct are linked to our own practice can we gradually summarize and create scientific research management theories that fit China's circumstances. This

is what Premier Zhou taught in the past, raising understanding to a high rationale from a foundation of wideranging practice.

The ordering of experiences in practice to form rational knowledge and knowledge that fits a pattern has another advantage, and that is it is easy to examine practices, and it is also easy to get reactions from all quarters. Inasmuch as other people have also encountered the situations you have experienced and the problems you have encountered, whether or not the laws you have distilled can solve the situations they have gone through or can solve the problems they are now facing will soon be reported back to you. In this way you can do further study and make additional summaries to improve the conclusions you have arrived at. Therefore, we should treasure our advantages, and pay attention to the voice of experience, making efforts to distill experience from practice and to introduce and study theories from abroad in combination with them. This should become our extremely important method of study.

I have spoken above about three methods of study. Naturally, these are only the most important ones, and the ones that are generally applicable for study. When we have a clear view of the basic methods, we will have a common foundation for the study of scientific research management, and we will be able the better to let a hundred schools of thought contend and hasten the building of our research management branch of learning.

II. Problems in the Relationship Among Scientific Research Management Science, Management Science, and Metascience

We have held two national metascience discussion meetings. The field of study of metascience is a fairly large one, and the way in which various countries refer to it are not entirely the same. There is also a difference in emphasis on what is studied. On the basis of China's circumstances, which branch of it should we study? Comrades involved in metascience have already discussed some views, and have proposed organization of forces for a cooperative division of labor in studying several branches of this field of study. The first is theoretical metascience, which consists principally of the laws of development of research science, the laws of technical development, and other theoretical problems. The second is called scientific economics, which consists mostly of the study of the effects of economics on science and the effects of science on economics. This problem is a very important one, and we have numerous problems that are not clear. For example, when foreign countries use concrete economic benefits to express the value of scientific research creations, we are not just sure about how this is calculated. The third is termed the study of scientific policies. The fourth is termed the study of scientific talent.

In addition to these four branches, I believe we have yet another important branch of science requiring study, namely the scientific management field of learning. What would be a good name for this discipline? Some comrades have suggested adding the word "study" making it the study of scientific research management. In foreign countries, however, the term management includes the meaning of dealing, so it might also be termed the study of scientific dealing. Naturally, if this term is to be used, scientists will disagree inasmuch as dealing has something of a commercial air about it, which scientists might feel

is too vulgar. To term it the study of scientific management also has some drawbacks. In Chinese, the term management conveys a sense of administration. Some scientists point out that you want less ministration and more rationality. Consideration might therefore be given to calling it the study of scientific research organization inasmuch as management work is, in fact, organizational work, and is really no more than the organization of all forces, and the organization of various research topics and individual research tasks. Everyone can present his own views to help find a better term.

Well then, what is the relationship among the study of scientific research management or the study of scientific dealing, or the study of scientific research organization to management science and metascience? Can we understand that it is both an integral part of management science and also an integral part of metascience? The study of scientific research management is a research management problem; therefore, it is a part of management science. However, the management problems it studies are not the usual management problems, but rather management problems in scientific research activities. This belongs to the category of metascience research and becomes a branch discipline in metascience. Its theoretical foundation has already been mentioned. It draws from management science and metascience. It uses the knowledge and concepts of management science and the knowledge and concepts of metascience. When the knowledge and concepts of these two fields are applied to the study of scientific research management problems, they form the study of scientific research management. In this sense, the study of scientific research management is an applied science, which applies management science and metascience theories to scientific research management tasks. Therefore, we comrades who are engaged in scientific research management studies cannot depart from the study of and research into management science and metascience. We must take nourishment to strengthen ourselves from these sciences, the more thoroughgoingly to study problems in scientific research management.

III. The Make-up of the Study of Scientific Research Management Science

Well then, just what problems are studies in scientific research management science? I shall now present seven by way of demonstration.

1. Study of Problems in the Scientific Research System

Problems in the scientific research system were raised earliest by Comrade Xiaoping in 1977. At that time, Comrade Xiaoping asked Comrade Fang Yi and me to provide a scientific research system for the reorganization of the scientific research system to make it one that fitted circumstances in China.

Problems in the system were very numerous. For example, the scientific research system in China consists of five major parts: the national defense industry system, the production industrial sector system, regional systems, institution of higher learning system, and the Chinese Academy of Sciences system. These five large systems are under the unified political direction of the Central Committee, and their policies are coordinated by the National Science Commission. However, much of their day to day activities are very loosely organized and not sufficiently intercoordinated, and this is a problem in the system.

As another example, how to coordinate the central and regional systems, the Academy of Science system and the system of each department in the central government, the military research system and the civil scientific research system is also a major system's probelm. In addition, in view of the regional distribution of research organizations and the subordinate relationships of each institute, figuring out which institute is superior and which institute is subordinate in a period of readjustment and restructuring is related to systems problems and requires study.

The Chinese Academy of Sciences also is facing problems pertaining to its organization. Prior to the "Cultural Revolution," the Chinese Academy of Sciences had 106 institutes. By the close of the "Cultural Revolution" only somewhat more than 40 remained, most of them individually organized. Now a number have returned, or have been newly founded, bringing research organizations to 118. Views on this matter are not entirely similar. Some think there is no need to have brought so many back, while others believe that inasmuch as many disciplines and many branches of service characterize the Academy of Sciences, the return of this number has been fundamentally correct. Just what is the case? What is to be done in the future? This is a systems problem we face.

Last year we worked together with the National Energy Commission in a joint operation, mostly with the energy office of the original Natural Resources Overall Examination Association, to run an energy research institute. The duties, expenses, and staffing of the research were defined and solved by the National Energy Commission, and we were responsible for the ideological and political work, and for the academic work. As a result, this institute developed well, solving the problem of linkage between the Academy of Sciences and units outside the academy. This method of running an institute is also a problem in scientific research systems. In short, the problems in scientific research systems faced by China and the Academy of Sciences are numerous, and they should be a major ingredient in research management science research.

2. Study of Research Organizations and Their Organizational Problems

Research institutions have problems in the foundation for and timing of their establishment, development, division into institutes, division into units, and disbandment, their location and requirements. These problems are very complex. Instances in which organizational problems are fairly prominent now, and particularly when organization of institutes urgently require solution, should be major ingredients for scientific research management science study.

Research institutes differ from the usual grassroots units. They are at once both a grassroots unit and a cell in society, and are an academic institution the personnel of which may have attained the highest levels or may be the supreme authorities in the country in a particular discipline or academic field. This determines that institutes should have a little more organizational authority. Unless they do, the abilities of these scientists may be limited in their full play.

Policy organizations for institutes are also a problem. In the operation of people's democratic dictatorship in China, the national and local national

people's congresses exercise state authority. Reflecting this spirit, the academic organization that is the Academy of Sciences designated the Plenary Conference of Committee Members in All Academic Fields the policy organization of the entire academy. How are the institutes run? There are three ideas now. One is that political and economic decisions and decisions on matters pertaining to worker and employee welfare should be decided by an employees and workers conference, and academic decisions should be the precinct of an academic commission. The problem with this idea lies in having two decision making organizations in existence in institutes at the same time. Another idea is that since institutes do mostly academic work, therefore a conference of researchers above the rank of assistant researcher in each institute should be the policy making organization. This idea also poses problems. The work of an institute touches on overall party, government, trade union, and youth league matters. Without authority to make decisions on these matters, how can they function? The third idea is to have research personnel above the rank of assistant researcher elect an academic committee on which also sit representatives of the party, the government, the trade union, and the youth league to form an institute affairs conference, or an institute affairs committee, invested with decision making authority.

The party leadership system in institutes also has two views now. One proposal is a continuation of the system of institute director responsibility under leadership of the CCP Committee. One suggestion is trial operation of an institute director system, the CCP Committee playing a supervisory and guaranteeing role. The Central Committee has indicated that the institute director system under leadership of CCP committees is not to be further changed, and some pilot projects for the institute director system may be run. This is to say that this problem still requires our study and our practice. Naturally, the urgent question of the moment is proper separation between party and government and strengthening of ideological and political work. The organizational problems are, in fact, problems of a system of responsibility. Under a situation in which the programs for operating the academy are well defined, and under which the planning personnel, materials and operating expenses, as well as political and ideological work are substantially normal and under the guidance of the correct line and policies of the CCP Central Committee, the quality of an institute's work will be determined by whether or not it is able to perfect a democratic organization and a party leadership organization throughout the institute. This is to say that in addition to taking responsibility for its own leadership, the academy must also place responsibility for doing a good job in institutes on institute affairs committees, on directors of institutes, and on the masses of staff and workers, and on CCP committees and all members of the party and the youth league. Without a system of responsibility, there can be no efficiency.

3. Study of Problems in the Structure of Research Units

Structural problems include equitable proportioning of personnel in all parts of the total organization, how each part coordinates its activities, how completion of key tasks is assured in each unit, and how to lay different stress on the work of a system at different times so as to increase research work efficiency, etc. As far as the Academy of Sciences is concerned, problems

exist mainly in two areas. One is problems internal to perfecting the system; the other is the problem of buttressing liaison between upper and lower echelons.

Within the institutes of the Chinese Academy of Sciences are five systems. 1. The research system including theoretical research and practical research. 2. Research method system, which includes experimental equipment, information, library, printing, and production systems. 3. Research management system. 4. Logistics work system. 5. Ideological and political work system. Research work is the center piece, and all projects are indispensable. However, ideological and political work is a prerequisite and fundamental guarantee for the existence of our socialist research organizations. Today it must be vigorously strengthened. Finally logistical work, particularly whether housing is built in a planned and step by step way and is fairly allocated, is also a crucial problem affecting whether or not institutes in the academy can develop.

Echelon problems are yet another structural problem urgently requiring study. Too many echelons are no good. When echelons are numerous, blockages occur in their mid sections, and leaders in the upper echelons can easily become separated from the lower echelons. Too few echelons do not work either. The upper echelons directly manage lower echelons too much, and this may result in organizational looseness and inflexible guidance. Echelons in the Academy of Sciences today include the academy, branch academies, institutes, offices, and topical units. How to enhance liaison between upper and lower echelons very much merits study.

4. Study of the Problem of Research Planning

Research plans must center on difficult problems. This is a fundamental principle. Only when there are problems, people, funds, and materials can work go on. The problem here is how are problems set.

Ximeng [phonetic], who received a Nobel prize in economics in 1978, provided "three principles" that organizations must follow."

First, large units should have alrge objectives, and small units should have small objectives. Small objectives should be subordinate to large objectives. Put in the context of the realities of China's Academy of Sciences, all characteristics, programs, and tasks in the Academy of Sciences must be brought to bear on the problems. Problems cannot be divorced from this goal. This is a fundamental principle.

Second, each of the subordinate units should enjoy relative independence. To use his words, if the amount of information from outside that is transmitted in a unit is larger than the amount of information transmitted from within, this shows that the unit cannot function without the help of outside units, and the unit has lost its capability to exist. Conversely, only when a unit possess independent work capability can it continue to exist.

Third, the work process requires specialization. Only with specialization is it possible to have high efficiency.

I feel there is a lot of sense in what Ximeng said. Our selection of problems should also follow this principle. Our academy is a large system in which all institutes and all offices are sub-systems. The professional orientation of the entire academy should be manifested through the problems on which each individual institute is working. The goals of individual institutes should be synonymous with the overall goals of the academy as a whole. If they are not, the overall tasks of the academy as a whole will be destroyed. Today our general program and general task is "emphasis on both sides, and two services." The meaning of "emphasis on both sides" is that we are required to become the country's supreme academic institution, and the problems we work on should be representative of national standards. If our institutes work on all problems, doing a little bit but doing it on all subjects, it will inevitably be impossible to attain advanced standards, and the character of our academy will be changed. We should select those topics that have theoretical significance and practical value. For problems in the theoretical field, in particular, it is necessary to work on projects that possess their own distinguishing features and are creative in nature. This requires study of our principles for the selection of topics and our methods of evaluating topics so as to assure a seeking after major fields and major orientation.

Problems raised by "two services" are also numerous. During the period immediately following Liberation, our academy of sciences rendered a contribution in the elimination of locusts and plague. During the 1960's and 1970's, we also made great contributions in service to national defense projects. What projects are we wrestling with now? On the basis of national requirements and insofar as strength permits, we have made up our minds to do more work in the modernization of agriculture, in energy, and in building materials. How to select additional tasks and topics requires further study.

One further point. In doing research planning, it is necessary to consider manpower, funds and materials together. Without consideration of manpower, funds, and materials, the plans you work out will not be realizable. Little consideration was given to this aspect in the past. As a result, some projects encountered difficulties and could not be continued. However, exactly how to proceed is also a problem that research management science should study.

5. Study of the Problem of Research Ranks

Ranks is a military term borrowed for use here. Work involving ranks means the job of formulating organization and coordination of personnel. How large an organization does an institute need? What kinds of personnel does it need? What differences are there in personnel structure of different institutes? These are all problems having to do with the research ranks. We are weakest in this regard, having no ideas at all. Formerly when someone mentioned establishment of an institute, that meant people. Large institutes up to a thousand; medium size institutes 500 or 600; small institutes 200 or 300. As to the kinds of people needed, how many of each, and what kinds are lacking were never stated clearly. Research work today requires diverse specialists working together in order to move it ahead; therefore, selection of staff has to be done scientifically and equitably if it is to be effective.

Additionally is the problem of plans for training people. For every institute, how many of each kind of personnel should be trained, how many of these should be sent abroad and how many will be trained by ourselves, and how many will be sent to other units all require planning. Training is for the purpose of meeting needs. It is for the purpose of improving, after a period of time, a unit's research level and capability to make a greater contribution to the country. Without such explicit objectives, training work is doomed to failure from its inception.

The problem of verification of research cadres and research management cadres should become a major problem on which study is currently focused. There appear to be two points requiring separation. The first point is verification of effectiveness of cadre work. We have to look at their accomplishments and not look only at their academic record or professional levels. Academic records and professional levels only signify their capabilities for achievement; they are not the same as what they have done. Distinctions among achievements are of no less than four kinds. The first is excelling, achievements being very outstanding. The second is ability to handle any job. The third is inability to handle any job. The fourth is of no use whatsoever. Through such an overall examination, we will have some ideas about the promotion and deployment of cadres. For example, outstanding cadres may be entrusted to do the more important jobs. Those in the last two categories should be transferred to other work. The second point is that in analyzing current cadre shortcomings to find what training or other efforts should be made, it is necessary to begin with analysis of his basic qualifications and not look only at his achievements. Comrades in the Changchun Precision Optical Machine Institute presented a mathematical model for analyzing research management cadre qualifications, which is very interesting and can help us find areas in which we, ourselves, are deficient, thereby determining the orientation of our own efforts. I believe our political work cadres might also use this method to reveal their own inadequacies. The essence of this analysis is to stress that all categories of cadres should gradually become specialized and knowledgeable. This orientation is synonymous with the spirit of instructions from the Central Committee on the need for cadres to be made revolutionary, young, specialized, an knowledgeable.

6. Study of Academic Exchanges Inside and Outside the Country

Academic exchanges hold an important position in research work. Without academic exchange, research organizations become ponds of stagnant water. How can academic exchanges be done, and what forms of academic exchange are both effective and handy? These are problems that require solution in research management work.

Academic exchange methods are numerous. I would like to emphasize two points. The first point is the issue of research centers. Research centers are a most important modern form of exchange. For example, the research centers of France and Germany are characterized by having not many research personnel from this kind of research organization itself; less than half. Most are from elsewhere or students from abroad, or else research fellows. Those who go there mostly do research for a fixed period of time. Since they come from everywhere, think-

ing in all academic fields done there is very lively. Can we also do the same thing? We have some institutes in which research forces and laboratories are rather good. The problem now is mostly one of lack of buildings. We should make some trials little by little during the next several years.

The second point is the problem of visiting scholars. During the past several years, we have sent out very many visiting scholars, many of whom have already returned to China. They went to friendly foreign scientists to accept invitations to participate in research work or to exchange academic ideas from which both parties gained. But this was done in different ways. Some went to do work as research fellows (to study for degrees or not to study for degrees); some scholars able to work independently carried out joint research; some with specialities went to teach or make academic reports; and still others, who were internationally famous scholars, did work that was in the nature of academic guidance. All of this work should be summarized well so that our work in sending people abroad will become more effective.

7. Study of the Problem of Scientific Forecasting

In doing scientific management work, we must give constant attention to and chart the future orientation of our development. Study of scientific forecasting is the foundation for setting future orientation and development. For example, in what direction should our academy of sciences develop? In what direction should our institutes develop? These questions can be answered only on a foundation of what new situations may arise as determined by forecasting research.

The aforementioned seven points do not constitute the entire content of scientific research management science. They are only the relatively important aspects in it. As to what other ingredients for study should be included in scientific management science, everyone can discuss, and they can consider whether all major problems encountered in scientific research management should become objects for its study.

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'RENMIN RIBAO' ON SCIENTIFIC RESEARCH FREEDOM

HK051414 Beijing RENMIN RIBAO in Chinese 26 Feb 82 p 5

[Article by Gong Yushi [7895 5148 0037]: "Observe the Party's Resolutions and Safeguard the Freedom of Scientific Research"]

[Text] Can the party's resolutions draw conclusions on theoretical issues? This question cannot be raised in general terms, and we cannot say in general whether they can or cannot. Many theoretical issues need not and should not use the form of party resolutions to draw conclusions. However, on fundamental questions of theory involving the party's guiding ideology, the party must draw its own conclusions. Because a party like ours is not formed spontaneously. It is not merely a party formed for the sake of a certain specific action. Ours is a party guided and organized by a definite theory. The existence of the proletariat and its militant practice, when reflected in the theoretical thinking of science, become Marxism. Marxist theory combined with the workers' movements of various countries have given rise to revolutionary proletarian parties in various countries guided by Marxist theory and organized for concerted action. This use of a kind of scientific theory as the guiding ideology to determine our own objectives of struggle and to fix our own line and policies is a basic quality of our party. Therefore, on such fundamental questions of theory involving the theoretical basis of the guiding ideology of the party, the objectives of struggle and the party program and the theoretical basis of the line and policies of the party, the party not only can but also must, on the basis of full scientific study and by means of solemn democratic process, form resolutions, draw conclusions and determine its own common viewpoint and stand in order to unify the understanding of the whole party and observe them together. Only thus can the party become a disciplined and organized militant contingent guided by a common theory and take concerted action.

Then, why is there still uncertainty? This is because our party has made serious political and theoretical mistakes in the past. These mistakes were adopted in past resolutions and confirmed as "correct" by the party. Because of the authority and binding force of party resolutions, a demand was made on the theoretical circles to publicize and "expound and prove" these mistakes. Now, in summing up the events of the past, the comrades of the theoretical circles are constantly talking about this kind of historical lessons. We must indeed profoundly bear in mind this kind of historical lesson. However, we cannot simply draw the conclusion here that the party must not determine its own standpoint on such questions of theory or write it into its resolutions in

the future. We also cannot say that future theoretical work and party resolutions must not have any connection. We should make a concrete analysis of past experiences and lessons. We should say, the trouble is not in the resolutions made by the party on questions of theory or that the theoretical work of the party must comply with the party's resolutions. The trouble is in the political and theoretical mistakes in some of the resolutions made by our party in the past. Therefore, the key lies with the accuracy of major decisions made by our party in the political and theoretical field. If mistakes appear, we must make every effort to correct them more promptly and successfully. For this reason, I think we must:

1. Make every effort to place the decisions of our party in the political and theoretical field on the basis of scientific research. In other words, we must first use scientific research work to correctly formulate the resolutions of the party. All important resolutions of the party should be based on the scientific research of actual conditions and practical experiences and should be examined in practice to determine whether they are right or wrong. This is the primary demand.

2. Strictly observe democratic centralism, and develop the party's resolutions on a democratic basis. Different views must be fully discussed in a free and democratic manner. We not only must submit to the view of the majority, but we must also respect the view of the minority. We cannot suppress different views.

3. Continue to adopt a scientific and democratic attitude in implementing a resolution after it has been passed. We must correctly handle the relations between observing the resolution and exchanging views freely on questions of theory in accordance with the spirit of seeking truth from facts and the principle of democratic centralism. A resolution of the party reflects the common understanding of the party, this militant collective, in a certain period. This understanding, which is obtained from scientific research and from a democratic exchange of views, is considered by everyone as correct, and must be jointly observed and implemented by the whole party. Whether or not this understanding, which has a binding force on members of the collective, is correct or not must still be examined in practice. The free exchange of views within the procedure stipulated by democratic centralism is still allowed.

Therefore, a resolution itself should be not only a product of scientific research, but it at the same time is also the object of continued scientific research. Since it is a collective product based on democracy, it must at the same time give play to democracy in the process of implementation. A resolution of the party is not final. It is not an absolute thing that cannot tolerate research or discussion. When implementing and publicizing a resolution of the party, we must maintain a scientific and democratic attitude. We must see how we can continue to prove and examine it in actual life in connection with reality and continue to put forth new problems to push it forward and develop it. This is the endless process of practice and knowledge in repeated cycles.

At the same time, we must also see that the conclusion drawn by a resolution of the party on questions of theory should be limited to questions of a fundamental nature concerning the guiding ideology of the party, which the whole party must obtain common understanding of, in order to observe and take con-

certed action. However, we need not and should not let a resolution of the party draw conclusions on questions that do not belong to this nature or questions of a more academic nature. Even questions of theory which require the whole party to obtain common understanding of and which must be determined by a resolution of the party are also limited to their fundamental understanding and fundamental attitude. Those questions in the theoretical and academic field, which require more meticulous examination, also need not be determined by a resolution of the party. Regarding such questions, under the premise of unity in fundamental viewpoint and fundamental attitude, the development of meticulous examination may completely take the form of a free exchange of views.

The use of this kind of scientific and democratic attitude in formulating and handling party resolutions can unify the observation of party resolutions and the scientific research and scientific discussion on questions of theory. The basis of unity is the scientific attitude of seeking truth from facts or the organizational system of democratic centralism. Party resolutions have a binding force on party members and the theoretical workers of the party. Practice is the criterion for determining the truthfulness of our understanding. There is only this criterion, and there is no other. We cannot rely on democratic centralism, the majority, the upper level or resolutions to determine the truthfulness of our understanding. We can only rely on the examination of practice. This is a question of the theory of knowledge. For the sake of understanding objective truth, we must have freedom of scientific research and freedom of scientific discussion based on practice. Without this kind of freedom, the path to understanding truth will be blocked and the cause of the revolution will also suffer. These are questions of two different categories, but they are also closely related. We must try and unify them, and we can unify them. For our party is one which seeks truth and submits to truth, and as in the lyrics of "internationale," a party which "struggles for truth." If the democratic centralism of our party can be conscientiously observed and practiced, it can guarantee that our party becomes the mainstay of our understanding about the collective and enable us to understand truth. Even if mistakes were to appear, we would also be able to successfully correct them. The unity obtained on the basis of the scientific attitude of seeking truth from facts and the organizational system of democratic centralism is the unity of the Marxist theory on party building and the theory of knowledge. It is the unity of communists submitting to organization and submitting to the truth.

For the sake of correctly carrying out scientific discussion and scientific criticism on questions of theory, we must exert great efforts to eliminate the pernicious influence of the unscientific method of "mass criticism" which was prevalent for a long time in the past. For more than a decade after the latter part of the 1950's, the repeated criticism of the wrong line in the party basically confused right and wrong on many occasions. The confusing of right and wrong could only have been caused by the unscientific methods adopted by political criticism and theoretical criticism. This kind of criticism did not proceed form reality but determined a target of criticism beforehand and criticized it from all sides. There was no room for carrying out scientific research. In gathering materials for criticism, we did not objectively, comprehensively or historically study what these materials actually reflected but examined them with a strong prejudice to find what could be pieced together for

use against the target. We deliberately misinterpreted things, mixed up quotations, homed in on a single point without considering other aspects, extended the meaning of statements at will, raised minor issues to the level of principle, paid no attention to history and made no analyses. In the past, this metaphysical method of negating everything by "mass criticism" was quite serious in our political life and in our theoretical work and had a very deep influence on us. We must consciously strive to overcome this influence and break away from these old habits. Old habits are difficult to change, but we must change them. On questions of theory, regardless of whether criticizing erroneous things or discussing different views, we must adhere to the scientific attitude of seeking truth from facts. We would adhere to the scientific attitude of seeking truth from facts. We would not use the unscientific method of criticism even against our enemies, so how could we use it within our own ranks! Therefore, within our ranks and among our comrades, the discussion and criticism of views we consider to be wrong or inappropriate are permissible. This kind of criticism should be carried out with a solemn, scientific and realistic attitude. We must adopt the attitude of respecting objective reality, respecting historical facts, making analyses and allowing discussion. We must not adopt a frivolous, temperamental and unscientific attitude. Only in this way can we make advance in the scientific field.

There is also a question of the line of demarcation between open discussion and internal discussion. The "guiding principles for inner-party political life" stipulates: "If there are dissenting views on matters concerning the fundamental interests of the party and state, or major political questions of theory and policy that affect the overall situation, they can be discussed on appropriate occasions within the party. But when and how these should be discussed in the newspapers and magazines should be decided by the Central Committee. The party's journals should unconditionally publicize the party's line, principles, policies and political views. As for major political questions of theory and policy already decided by the Central Committee, if a party member has a dissenting view, he can raise it through the given organizational procedure, but he is absolutely not allowed to openly issue any statement opposing the decision of the Central Committee in newspapers or radio broadcasts. He is also not allowed to spread any view opposing the party's line, policies, principles and decisions among the masses. This is the discipline of the party." This stipulation is definitely not intended to stop our free research and discussion of party resolutions. It requires us to prudently handle this question in accordance with the discipline and principles of the party, the interests of the party and people and the demands of the struggle situation and to carry out scientific research and scientific discussion in the correct form and procedure.

In conclusion, I think that in these two aspects of observing the party's discipline and decisions and carrying out free scientific study and scientific discussion on questions of theory, it is entirely possible to achieve unity on the basis of the scientific attitude of seeking truth from facts and the organizational system of democratic centralism. As a militant organization, the party must have unified understanding, unified discipline and unified action. At the same time, as an organization of advanced elements of the Proletariat guided by the science of Marxism, it is necessary to establish its ideology and policies on a scientific basis in order to maintain the correctness of its guiding ideology. It is necessary to develop free scientific research and scientific discussion in order to achieve scientific understanding. These two aspects must be unified and can certainly be unified.

CSO: 4008 118

ADVANCES IN RADAR, TRACKING SYSTEMS DETAILED

Tracking System With Regenerative Feedback

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese No 6, 1981 pp 1-12

[Article by Wang Zuoying [3679 0155 5391] of Qinghua University: "Analysis of the Regenerative Feedback Tracking System"; This article received in October 1980 and finalized in March 1981]

[Text] Abstract

The regenerative feedback tracking system in an effective system for precise tracking of large dynamic targets. Because it is a multiple input and multiple output nonlinear system, in the past, we could only carry out quantitative studies[1,2] using the computer to solve the nonlinear dynamic equations of the system and obtain their numerical solution. This article uses the time domain operator to establish a mathematical model for the system and obtains the analytic expression for computing the precision of tracking by the system. Analysis shows that the error in tracking a target in powered flight by the system and the random error become an analytic and computational problem of the steady linear system in rectangular coordinates, and the mismatching error of tracking by the system is an analytic and computational problem of the steady linear system in spherical coordinates. Therefore, the results obtained are very suitable for engineering calculations and design.

I. Foreword

The spatial coordinates of a target of a radar telemetric system is a system in spherical coordinates. Therefore, it is natural for a classical radar tracking system to filter the waves of the signals in spherical coordinates. But because spherical coordinates are an inertia coordinates system, the expression of the spherical coordinates of the orbit of motion of the target frequently has a very wide frequency band, and this sharpens the conflict between the capability of the tracking system to respond rapidly to the motion of a target and the ability to suppress random interference.

Thus, frequently, the classical tracking system cannot adequately handle the requirements of highly precise tracking and tracking within a wide dynamic range demanded by modern aviation and space technology. The regenerative feedback tracking system is an effective system to solve the conflict described above.

The time domain operator method proposed in this article establishes a precise mathematical model for the system and obtains corresponding analytic expressions. The method of the time domain operator itself is an algebraic method, and the results obtained can be understood within the context of the concepts of the method of classical frequency domains, therefore it is very suitable for engineering calculations.

II. Model of the System

The block diagram of the regenerative feedback tracking system is illustrated in Figure 1.

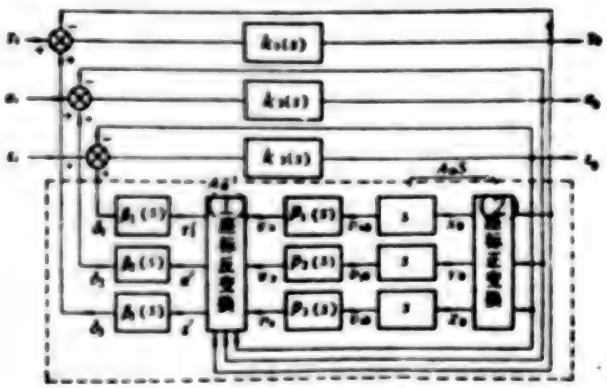

Figure 1. Block diagram of a regenerative feedtack tracking system

Key: (1) Inverse transformation of coordinates
(2) Normal transformation of coordinates

The difference between this system and the classical tracking system is that a regenerative feedback channel (or called computer-aided tracking channel)(1) as shown in the block of dotted lines in Figure 1 has been added. This channel transforms the telemetric values r_0, a_0, θ_0 of the target measured by the system in spherical coordinates into velocities v_{xo}, v_{yo}, v_{zo} in rectangular coordinates, and it smoothes the filtered waves in the wave filter with $P_1(s)$, $P_2(s)$, $P_3(s)$ as its three transfer functions. After being smoothed, the velocities v_x, v_y, v_z in rectangular coordinates are transformed into corresponding velocities in spherical coordinates r', a', ε' by inverse transformation of the rectangular coordinates v_x, v_y, v_z to obtain appropriate regenerative feedback control values. Finally, through a signal forming network with transfer functions $\beta_1(s)$, $\beta_2(s)$, $\beta_3(s)$, the required regenerative feedback signals δ_r, δ_a, δ_ε are obtained and sent to the corresponding master channels, thus completing the entire regenerative feedback process.

Besides the two transformations of coordinates in the regenerative feedback tracking system, the remaining domains are all steady linear domains of population parameters. Their signal transformation function can be described by transfer functions of the classical frequency method. But because of the introduction of a nonlinear transformation of coordinates into the closed domain system, the entire system becomes a highly nonlinear multiple input and multiple output system. Because the classical frequency method is ineffective for this kind of nonlinear systems, therefore, quantitative analysis of the system in the time domain must be carried out. The following starts out from the regenerative feedback channel, establishes a mathematical model of the system in the time domain and explains the essentials of the time domain operator method.

First, the output signal $\Psi_0 \triangleq [\gamma_0 \alpha_0 \beta_0]^T$ is transformed into velocities in rectangular coordinates $X_0 \triangleq [x_0 y_0 z_0]^T$:

$$V_0 = [v_{x_0} v_{y_0} v_{z_0}]^T \tag{1}$$

where all quantities in the equation are time functions, and for convenience, time (t) is omitted. Because

$$x_0 = r_0 \cos \varepsilon_0 \cos \alpha_0, \quad y_0 = r_0 \cos \varepsilon_0 \sin \alpha_0, \quad z_0 = r_0 \sin \varepsilon_0 \tag{2}$$

thus,

$$V_0 \triangleq dX_0/dt = A_0 \Psi_0' \tag{3}$$

where Ψ_0' represents the time derivative of Ψ_0, i.e., the velocity vector in spherical coordinates. A_0 is the normal transformation matrix of the coordinates:

$$A_0 = \begin{bmatrix} \cos \varepsilon_0 \cos \alpha_0 & -r_0 \cos \varepsilon_0 \sin \alpha_0 & -r_0 \sin \varepsilon_0 \cos \alpha_0 \\ \cos \varepsilon_0 \sin \alpha_0 & r_0 \cos \varepsilon_0 \cos \alpha_0 & -r_0 \sin \varepsilon_0 \sin \alpha_0 \\ \sin \varepsilon_0 & 0 & r_0 \cos \varepsilon_0 \end{bmatrix} \tag{4}$$

Because A_0 contains the output quantities r_0, α_0, ε_0 of the system, therefore the system is nonlinear.

Second, the smoothing of the velocity signals by the transfer functions $p_i(s)$ ($i = 1, 2, 3$) of the wave filter is regarded as a type of linear computation of input signals in the time domain, and the relationship between input and output is:

$$V = P(s)V_0 \tag{5}$$

where V_0, V are respectively the velocities in rectangular coordinates before and after the smoothed filter wave. They are all time functions. $P(s)$ is understood as a linear operator

$$P(s)\triangleq\begin{bmatrix} p_1(s) & 0 & 0 \\ 0 & p_2(s) & 0 \\ 0 & 0 & p_3(s) \end{bmatrix} \tag{6}$$

in the time domain. We know from Laplace transform that when p(s) is a time domain operator, its variable s is a differential operator s = d/dt, and p(s) is regarded as a function of the differential operator s.

Inverse transformation of coordinates transforms the velocity V in rectangular coordinates into a corresponding velocity $\bar{V}'$ in spherical coordinates. The relationship between them obeys equation (3). Therefore,

$$\bar{V}' = A_0^{-1}V \tag{7}$$

where A_0^{-1} is the inverse matrix of A_0:

$$A_0^{-1}=\begin{bmatrix} \cos\varepsilon_0\cos\alpha_0 & \cos\varepsilon_0\sin\alpha_0 & \sin\varepsilon_0 \\ -\sin\alpha_0/r_0\cos\varepsilon_0 & \cos\alpha_0/r_0\cos\varepsilon_0 & 0 \\ -\sin\varepsilon_0\cos\alpha_0/r_0 & -\sin\varepsilon_0\sin\alpha_0/r_0 & \cos\varepsilon_0/r_0 \end{bmatrix} \tag{8}$$

The feedback forming domain is also a wave filter with a transfer function $\beta_i(s)$ (i=1, 2, 3). Let

$$\delta\triangleq\begin{bmatrix}\delta_1\\ \delta_2\\ \delta_3\end{bmatrix},\quad B(s)\triangleq\begin{bmatrix} \beta_1(s) & 0 & 0 \\ 0 & \beta_2(s) & 0 \\ 0 & 0 & \beta_3(s) \end{bmatrix} \tag{9}$$

B(s) is also a time domain operator. Its effect on the input and the signal $\bar{V}'$ can be written as

$$\delta = B(s)\ \bar{V}' \tag{10}$$

Substituting equations (3), (5) and (7) one after the other, and utilizing the relation $\bar{V}' = s\bar{V}_0$, equation (10) can be written as

$$\delta = B(s)A_0^{-1}P(s)A_0s\bar{V}_0 \tag{11}$$

Equation (11) is the transformation of the signal by the regenerative feedback channel. In the equation, A_0 , A_0^{-1} are time functions while B(s), P(s) are functions of the differential operator s. It is worth pointing out that the order of multiplication of each operator in the equation cannot be changed at will. The condition in which the order of multiplication of the operators can be changed will be discussed later.

Now, let us establish the mathematical model for the whole closed domain system. According to equation(11), the transformation of signals by the

regenerative feedback channel is equivalent to the time domain operator defined by the following equation:

$$T(s,t)\triangleq B(s)A_0^{-1}P(s)A_0 s \tag{12}$$

Let

$$K(s)=\begin{bmatrix} k_1(s) & 0 & 0 \\ 0 & k_2(s) & 0 \\ 0 & 0 & k_3(s) \end{bmatrix} \tag{13}$$

Then the equivalent block diagram of the system is shown in Figure 2. Thus, we have:

$$\begin{aligned} \mathbf{V}_0 &= K(s)[\mathbf{V}_i-\mathbf{V}_0+\delta] \\ &= K(s)\mathbf{V}_i-K(s)\mathbf{V}_0+K(s)B(s)A_0^{-1}P(s)A_0 s\mathbf{V}_0 \end{aligned} \tag{14}$$

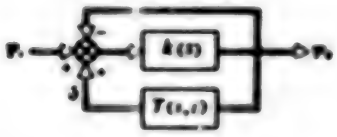

Figure 2. Block diagram of the vector structure of the system

After a simple algegraic transformation, we obtain:

$$\begin{aligned} &[E+K(s)-K(s)B(s)s]\mathbf{V}_0 \\ &=K(s)\mathbf{V}_i-K(s)B(s)A_0^{-1}[E-P(s)]A_0 s\mathbf{V}_0 \end{aligned} \tag{15}$$

where $\mathbf{V}_i$ represents the input vectors of the system in spherical coordinates, $\hat{E}$ is the constant operator (i.e., 3X3 unit matrix).

Equation (15) is the mathematical model that describes the work of the whole regenerative feedback tracking system. Because A_0 and A_0^{-1} include the output r_0, a_0, ε_0 of the system, equation (15) is a nonlinear operator equation. The quantitative analysis of performance of the system becomes a solution of that nonlinear operator equation.

III. Precision of Tracking by the System

In the following, we will solve equation (15) to find the analytic expression for calculating the precision of tracking by the system. Let the real values of the coordinates of the target be:

$$\mathbf{V}_T=[r_T,\ a_T,\ \varepsilon_T]^T \tag{16}$$

The random interference of the input signal is:

$$N_i = [n_r, n_\alpha, n_\varepsilon]^T \tag{17}$$

Then $$\Psi_i = \Psi_T + N_i \tag{18}$$

Assume that the tracking error is:

$$\Delta\Psi = [\Delta r, \Delta\alpha, \Delta\varepsilon]^T \tag{19}$$

then $$\Psi_0 = \Psi_T + \Delta\Psi \tag{20}$$

In the second term on the right side of equation (15)

$$A_0 s\Psi_0 = V_0 = sX_0 = s(X_T + \Delta X) = V_T + s\Delta X \tag{21}$$

where X_T, ΔX are the values corresponding to Ψ_T, $\Delta\Psi$ in rectangular coordinates, and $V_T = sX_T$ is the expression of the velocity of the target in rectangular coordinates.

$$\Delta X = (\partial X_T/\partial r)\Delta r + (\partial X_T/\partial\alpha)\Delta\alpha + (\partial X_T/\partial\varepsilon)\Delta\varepsilon = A_T\Delta\Psi \tag{22}$$

We can use the right side of the expression of the above equation as a substitute for ΔX because after the system enters tracking status, Δr, $\Delta\alpha$, $\Delta\varepsilon$ are all very small, and the high order infinitessimal quantities can be ignored. A_T is the transformation matrix of the coordinates obtained after substituting the output r_0, α_0, ε_0 in matrix A_0 by the corresponding coordinates r_T, α_T, ε_T. Substituting equation (22) into equation (21), we have:

$$A_0 s\Psi_0 = A_T s\Psi_T + sA_T\Delta\Psi \tag{23}$$

Here, we have used the relation $V_T = A_T s\Psi_T$

After substituting equations (18), (20) and (23) into equation (15) and rearranging the terms, we have

$$\begin{aligned}[E + K(s) - K(s)B(s)s]\Delta\Psi = {} & [K(s)B(s) - E]\Psi_T + K(s)N_i \\ & - K(s)B(s)A_0^{-1}[E - P(s)]\cdot[A_T s\Psi_T + sA_T\Delta\Psi]\end{aligned} \tag{24}$$

Because the design of the system will always make the distortion of the velocity signals $V_T = A_T s\Psi_T$ by P(s) very small, and $sA_T\Delta\Psi$ itself is also a very small quantity, therefore the signal following the operator A_0^{-1} in the above equation is a first order infinitessimal quantity. Expanding A_0^{-1} at Ψ_T and taking the first order approximation, we have:

$$A_0^{-1} \triangleq A^{-1}(\Psi_T + \Delta\Psi) = A^{-1}(\Psi_T) + \Delta A^{-1} = A_T^{-1} + \Delta A^{-1}$$

$$\Delta A^{-1} = \frac{\partial A_T^{-1}}{\partial r}\Delta r + \frac{\partial A_T^{-1}}{\partial \alpha}\Delta\alpha + \frac{\partial A_T^{-1}}{\partial \varepsilon}\Delta\varepsilon$$

ΔA^{-1} is also a first order infinitessimal quantity, therefore its effect in equation (24) can be neglected, thus, equation (24) becomes:

$$\begin{aligned}[E+K(s)-K(s)B(s)s]\Delta\Psi &= [K(s)B(s)s-E]\Psi_T \\ &+ K(s)B(s)A_T^{-1}[P(s)-E]A_T s\Psi_T + K(s)N_i \\ &+ K(s)B(s)A_T^{-1}[P(s)-E]sA_T\Delta\Psi\end{aligned} \tag{25}$$

All the operators K(s), B(s), P(s) in the s functions in equation (25) are diagonal matrices. According to our understanding of the time domain of these operators, the computational relationship between them is a commutative algebraic system. Therefore, if we multiply both sides of equation (25) by the inverse operator of the left side of the equation, we have:

$$\begin{aligned}\Delta\Psi = &\frac{K(s)B(s)s-E}{E+K(s)-K(s)B(s)s}\Psi_T + \frac{K(s)B(s)}{E+K(s)-K(s)B(s)s} \\ &\cdot A_T^{-1}[P(s)-E]A_T s\Psi_T \\ &+ \frac{K(s)}{E+K(s)-K(s)B(s)s}N_i - \frac{K(s)B(s)}{E+K(s)-K(s)B(s)s} \\ &\cdot A_T^{-1}[E-P(s)]sA_T\Delta\Psi\end{aligned} \tag{26}$$

Let
$$W(s) \triangleq \frac{K(s)}{E+K(s)-K(s)B(s)s} \triangleq \begin{bmatrix} W_1(s) & 0 & 0 \\ 0 & W_2(s) & 0 \\ 0 & 0 & W_3(s) \end{bmatrix} \tag{27}$$

Then
$$\begin{aligned}&\{E+W(s)B(s)A_T^{-1}[E-P(s)]sA_T\}\Delta\Psi \\ &= [W(s)-E]\Psi_T + W(s)B(s)A_T^{-1}[P(s)-E]A_T s\Psi_T + W(s)N_i\end{aligned} \tag{28}$$

This is the operator equation satisfied by the tracking error $\Delta\Psi$. Because A_T and A_T^{-1} are all functions of the target coordinates Ψ_T only, they are unrelated to the output Ψ_0. Therefore, it is a time variant linear operator equation. Calculations of the tracking error $\Delta\Psi$ becomes a problem of solving this operator equation. Before discussing the general solution of this operator equation, let us first discuss the solution of the tracking velocity of a symmetrically structured regenerative feedback tracking system. In this system, the operators are designed to be

$$\begin{aligned}k_1(s) = k_2(s) = k_3(s) &= k_0/s \\ \beta_1(s) = \beta_2(s) = \beta_3(s) &= 1/k_0\end{aligned} \tag{29}$$

Substituting the above equation into equation (27), we have W(s) = E, thus equation (28) becomes

$$\left\{E+A_T^{-1}\frac{1}{k_0}\left[E-P(s)\right]sA_T\right\}\Delta\Psi=A_T^{-1}\frac{1}{k_0}\left[E-P(s)\right]A_TsV_T+N_i \tag{30}$$

The inverse of the left operator of the equation

$$\left\{E+A_T^{-1}\frac{1}{k_0}\left[E-P(s)\right]sA_T\right\}^{-1}=A_T^{-1}\frac{k_0E}{k_0\Gamma\cdot\ [E-P(s)]s}A_T \tag{31}$$

Thus

$$\Delta\Psi=A_T^{-1}\frac{E-P(s)}{k_0E+[E-P(s)]s}A_TsV_T+A_T^{-1}\frac{k_0E}{k_0E+[E-P(s)]s}A_TN_i \tag{32}$$

Equation (32) is an analytic expression of the tracking error of the system. According to equation (32), when the vectors V_T of the coordinates of motion of the target and the randomly interfering noise N_i of the input of the system are given, we can obtain the tracking error $\Delta\Psi$ of the regenerative feedback system in tracking the velocity of the target. The first term on the right side of the equation is the lagging error of tracking created by the powered flight of the target, the second term is the random error of tracking.

If we multiply the two sides of equation (32) simultaneously on the left by A_T, and if we take into consideration $\Delta X = A_T\Delta\Psi$, $V_T = A_TsV_T = sX_T$ and $\Delta X_i = A_TN_i$, then

$$\Delta X=\frac{[E-P(s)]s}{k_0E+[E-P(s)]s}X_T+\frac{k_0E}{k_0E+[E-P(s)]s}\Delta X_i \tag{33}$$

This is a decoupling steady linear system in the rectangular coordinates system. Figure 3 illustrates the block diagram of its equivalent structure.

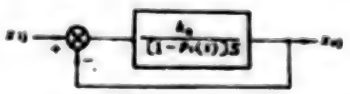

Figure 3. Block diagram of the equivalent structure for velocity feedback

In the diagram $x_{i1} = x_i$, $x_{i_2} = y_i$, $x_{i_3} = z_i$, $x_{01} = x_0$, $x_{02} = y_0$, $x_{03} = y_0$. This result is somewhat unexpected. The velocity tracking regenerative feedback system is a steady system in rectangular coordinates. Since we have converted the system into a steady linear system in rectangular coordinates, the analysis and design procedures of this type of a system can be carried out using the frequency method in the classical theory of cybernetics. The only difference is that such analysis and design procedures are carried out in the rectangular coordinates system, not in the spherical coordinates system. Also, according to the properties of the operator of the s function previously described, these operator functions are the transfer functions of this system in the ordinary sense by classical definition.

For example, the operator before the term X_T on the right side of equation (33) can be directly understood as the transfer function of the error of the system. Let us explain with an example. Let

$$P_1(s)=P_2(s)=P_3(s)=\frac{1}{(1+\tau s)^4}$$

$$\frac{[E-P(s)]s}{k_0E-[E-P(s)]s}=\frac{1}{k_0}\left\{4\tau s^2-10\tau^2s^3+\left(20\tau^3-\frac{16\tau^2}{k_0}\right)s^4+\cdots\cdots\right\}$$

The lagging error of powered flight

$$\Delta X_T=\frac{4\tau}{k_0}\frac{dV_T}{dt}-10\tau^2\frac{d^2V_T}{dt^2}+\cdots\cdots$$

When the target flies in a straight line at uniform velocity, the system will not produce a lagging error in tracking because V_T^{I} = V_T^{II} = ... = 0. If the target flies in the x direction at acceleration a, then

$$\Delta X_T = 4\tau a/k_0$$

When k_0 = 10 1/s, τ = 0.1s, = 5g, Δx_T = 1.8 m.

The second term in equation (33) is the random error. It can be described by the noise channel frequency band of the equivalent closed domain transfer function before N_i.

Some characteristics of the property and the design of the regenerative feedback tracking system will be discussed later. Now, let us study the solution of the operator equation (28) in a more general situation. The key to the problem is to find the inverse operator of the left side of the equation. For this, we need to study the characteristics of W(s)B(s) in the operator on the left side of the equation. We have seen in the process of solving $\Delta\Psi$ of the tracking velocity of a symmetrically structured regenerative feedback system that under ideal conditions, W(s)B(s) = E/k_0 is a constant matrix with equal diagonal elements. Therefore we can exchange the order of multiplication of the matrix and A_T^{-1}. But in actual engineering, because of the limitations in technology and testing techniques, the structure of each channel is not symmetric and the operator W(s)B(s) is not a constant matrix. Therefore, studying the solution of the operator equation when the system departs from a symmetric structure and when the transfer functions $k_i(s)$ (i = 1, 2 3) of the main channels are not ideal integral domains has important practical significance. Even though in the actual sytem, the situation will not be like those discussed above, W(s)B(s) = E/k_0, having an infinite frequency bandwidth, but it can almost always be regarded that W(s)B(s) has a sufficiently wide frequency band. Thus, from the discussion in Appendix I we know that at this time, if the diagonal elements of W(s)B(s) and A_T^{-1} can be exchanged without bringing about visible errors in calculation. To solve the difficulty of unequal diagonal elements of W(s)B(s) caused by structural asymmetry, we subject the operator on the left side of equation (28) to the following transformation. Let

$$U=\{E+W(s)B(s)A_T^{-1}[E-P(s)]sA_T\} \tag{34}$$

$$C\triangleq\frac{1}{3}\sum_{i=1}^{3}W_i(0)\beta_i(0)\begin{bmatrix}1/W_1(0)\beta_1(0) & 0 & 0\\ 0 & 1/W_2(0)\beta_2(0) & 0\\ 0 & 0 & 1/W_3(0)\beta_3(0)\end{bmatrix} \tag{35}$$

In this way, the operator W(s)B(s)C can be regarded as symmetric within a very wide frequency band. Thus,

$$\begin{aligned}U&=\{E+W(s)B(s)CC^{-1}A_T^{-1}[E-P(s)]sA_T\}\\&=C^{-1}A_T^{-1}\{E+W(s)B(s)C[E-P(s)]s\}\\&\quad\cdot\{E+(E+W(s)B(s)C[E-P(s)]s)^{-1}A_T(C-E)A_T^{-1}\}A_T\end{aligned} \tag{36}$$

The inverse of U

$$\begin{aligned}U^{-1}&=A_T^{-1}\{E+(E+W(s)B(s)C[E-P(s)]s)^{-1}A_T(C-E)A_T^{-1}\}^{-1}\\&\quad\cdot\{E+W(s)B(s)C[E-P(s)]s\}^{-1}A_TC\end{aligned} \tag{37}$$

Let
$$R=E+(E+W(s)B(s)C[E-P(s)]s)^{-1}A_T(C-E)A_T^{-1} \tag{38}$$

then
$$U^{-1}=A_T^{-1}R^{-1}\{E+W(s)B(s)C[E-P(s)]s\}^{-1}A_TC \tag{39}$$

In appendix II, we have found the series for R^{-1}, and we have proven that when the system does not depart a lot from symmetry, we can regard $R^{-1}=E$. Appendix II gives the error brought about by such an approximation. Thus we have

$$U^{-1}=A_T^{-1}\{E+W(s)B(s)C[E-P(s)]s\}^{-1}A_TC \tag{40}$$

Mutiplying the two sides of the operator equation (28) by the inverse operator U^{-1} on the left, we obtain the formula for calculating the tracking error of the system:

$$\begin{aligned}\Delta\Psi&=A_T^{-1}\{E+W(s)B(s)C[E-P(s)]s\}^{-1}A_TC[W(s)-E]\Psi_T\\&\quad+A_T^{-1}\{E+W(s)B(s)C[E-P(s)]s\}^{-1}A_TCW(s)B(s)A_T^{-1}[W(s)-E]A_Ts\Psi_T\\&\quad+A_T^{-1}\{E+W(s)B(s)C[E-P(s)]s\}^{-1}A_TCW(s)N,\end{aligned} \tag{41}$$

According to this formula, when the system's structural parameters and the parameters of motion of the target are given, we can calculate the tracking error of the system. The tracking error consists of three parts: the first

term in the formula is the error caused by imperfections ($W(s) \neq E$) in the design of the system or manufacturing. We call it the mismatching error. To eliminate this error in equation (27) so that $W(s) = E$, the following must be satisfied:

$$K(s)B(s)s = E \tag{42}$$

This equation is called the system's matching condition. The meanings of the second and third terms on the right side of equation (41) correspond respectively to the meanings of the first and the second terms of equation (31).

To further simplify engineering computation, we see that because the operator before A_T in the first term on the right side of equation (41) is a symmetric operator, and relative to A_T, the frequency band is very wide, thus, based on the discussion in Appendix I, A_T can be moved to the front. The A_T in the second term can be moved to the back of $CW(s)B(s)$. The third term requires the following transformation. Let

$$C_0 = \frac{1}{3}\sum_{i=1}^{3} W_i(0)B(0), \quad C_1 = C_0 B^{-1}(0), \quad C_2 = W^{-1}(0) \tag{43}$$

Then C defined by equation (35) is

$$C = C_1 C_2 \tag{44}$$

In equation (41), the operator in the third term

$$A_T\, CW(s) = A_T\, C_1 C_2 W(s) \tag{45}$$

$C_2W(s)$ is symmetric within a very wide frequency band, therefore we have

$$A_T\, CW(s) = C_2 W(s) A_T C_1 \tag{46}$$

Considering the above discussion, equation (41) becomes

$$\begin{aligned}\Delta W = & \frac{C[W(s)-E]}{E+CW(s)B(s)s[E-P(s)]}\Psi_T \\ & + A_T^{-1}\frac{CW(s)B(s)[E-P(s)]}{E+CW(s)B(s)s[E-P(s)]}A_T s\Psi_T \\ & + A_T^{-1}\frac{C_2 W(s)}{E+CW(s)+B(s)s[E-P(s)]}A_T C_1 N_i\end{aligned} \tag{47}$$

If the mismatching error of the system is expressed in spherical coordinates $\Delta\Psi_D$, and the error caused by powered flight of the target and the error caused by the input interference N_i are expressed in rectangular coordinates ΔX_T, ΔX_N, then

$$\Delta\Psi_D=\frac{C[W(s)-E]}{E+CW(s)B(s)s[E-P(s)]}\Psi_T$$
$$\Delta X_T=\frac{CW(s)B(s)[E-P(s)]s}{E+CW(s)B(s)s[E-P(s)]}X_T \tag{48}$$
$$\Delta X_N=\frac{C_2W(s)}{E+CW(s)B(s)s[E-P(s)]}\Delta X_{ei}$$

Here, $\Delta X_{ei} \triangleq A_T C_1 N_i$. It is the expression of the rectangular coordinates of the equivalent random interference C_1N_i of the input after the random interference N_i of the input has been weighted by the matrix C_1. It can be seen from equation (48) that even when the system structure is asymmetric and when the matching condition (42) is not satisfied, the system can still become a steady linear system. Also, because all the operators on the right side of equation (48) are diagonal matrices, the components of each coordinate system are mutually decoupled. Therefore, calculations of the design of the system can be carried out according to the above equation by the well-known frequency method in the classical theory of cybernetics. The only difference is that the analytical calculation of the mismatching error is carried out in spherical coordinates while the analytical calculation of the lagging error in tracking caused by the powered flight of the target and the random error caused by input random interference are carried out in rectangular coordinates.

An asymmetrically structured and mismatched regenerative feedback system for tracking velocity is given in the following as an example to further explain the effects upon the performance of the system by these two unideal factors.

Let the open domain gain of each main channel of the system be unequal, as follows:

$$K(s)=\frac{1}{s}\begin{bmatrix}k_1 & 0 & 0\\ 0 & k_2 & 0\\ 0 & 0 & k_3\end{bmatrix}=\frac{k}{s},\qquad k=\begin{bmatrix}k_1 & 0 & 0\\ 0 & k_2 & 0\\ 0 & 0 & k_3\end{bmatrix} \tag{49}$$

To eliminate the mismatching error of the system, we can take $B(s) = E/k_0$ according to the matching condition (42). But because of the limitations in the precision of manufacturing the components and the precision of adjustment of the system, actually

$$B(s)=\frac{E+\xi}{k},\qquad \xi=\begin{bmatrix}\xi_1 & 0 & 0\\ 0 & \xi_2 & 0\\ 0 & 0 & \xi_3\end{bmatrix} \tag{50}$$

ξ is called the mismatching matrix of the system. Substituting (49) and (50) into equations (27), (35) and (44) and (45), we have

$$W(s)=k/(k-\xi s),\quad C=C_0k/(E+\xi),\quad C_1=E,\ C_2=C \tag{51}$$

Equation (48) can be written as:

$$\Delta\Psi_D=\frac{(E+\xi)^{-1}\xi s}{k_0'E+[E-P(s)]s-\frac{\xi}{k_0'k}s}\Psi_T$$

$$\Delta X_T=\frac{[E-P(s)]s}{k_0'E+[E-P(s)]s-\frac{\xi}{k_0'k}s}X_T$$

$$\Delta X_N=\frac{k_0'E}{k_0'E+[E-P(s)]s-\frac{s}{k_0'k}s}\Delta X_i \qquad (52)$$

The $k_0' \triangleq C\bar{0}_1^1$ in the formula is an equivalent open domain gain. When the system structure is symmetric and when there is no mismatching, $k_0' = k_0$. Therefore, k_0' is a quantity of the same magnitude as the system's open domain gain. Thus, the s term in the denominator in the above equation can be neglected. The second and third terms in equation(52) and equation (33) have completely different forms. The difference is that k in the latter has been changed to k_0' E. From this we conclude that asymmetry of the system exerts a very slight effect upon the performance of the system. The mismatching of the system only causes the system to produce a mismatching error $\Delta\Psi_D$, for example, when $k_0' = 10 \cdot 1/s$, $\xi_2 = 0.1$, and when the azimuth velocity of the target $\alpha' = 1/s$, $\Delta\alpha = 10^{-2} = 10$ milliradians. Therefore, the mismatching error in tracking caused by mismatching is serious, and this should be fully taken into consideration.

When the system is structurally symmetric, C = E, equation (48) becomes

$$\Delta\Psi_D=\frac{W(s)-E}{E+W(s)B(s)s[E-P(s)]}\Psi_T$$

$$\Delta X_T=\frac{W(s)B(s)[E-P(s)]s}{E+W(s)B(s)s[E-P(s)]}X_T$$

$$\Delta X_N=\frac{W(s)}{E+W(s)B(s)s[E-P(s)]}\Delta X_i \qquad (53)$$

Or from equation (27), we have:

$$\Delta\Psi_D=\frac{K(s)B(s)s-E}{E+K(s)-K(s)B(s)sP(s)}\Psi_T$$

$$\Delta X_T=\frac{K(s)B(s)s[E-P(s)]}{E+K(s)-K(s)B(s)sP(s)}X_T$$

$$\Delta X_N=\frac{K(s)}{E+K(s)-K(s)B(s)sP(s)}\Delta X_i \qquad (54)$$

When the system is structurally symmetric and is matching, $\Delta V_D = 0$

$$\Delta X_T = \frac{E - P(s)}{K(s) + E - P(s)} X_T$$

$$\Delta X = \frac{K(s)}{K(s) + E - P(s)} \Delta X_i \tag{55}$$

At this time, the equivalent open domain transfer function of the system is

$$K_e(s) \triangleq \frac{K(s)}{E - P(s)} \tag{56}$$

The characteristics of the expression of the flight orbit of the target in rectangular coordinates are high velocity and low acceleration. Therefore, according to the classical theory of cybernetics, Kσ(s) should be designed as a type II system which includes two integral domains. For example, we can design K(s) as a type I system which includes one integral domain and design P(s) as a low-pass wave filter with P(o) = E. Of course, it is not necessary to make K(s) into an ideal integrator, the important thing is to satisfy equation (42) of the matching condition.

Because the acceleration of the rectangular coordinates of the target is small, the equivalent open domain gain of the system can be made very small. Thus, the bandwidth of the closed domain of the system can be very small [the operator of the second equation in equations (55) is an equivalent closed domain transfer function], so that the ability of the system to suppress interference is greatly improved.

To prove the accuracy of the analytic formula of the tracking error obtained above, we used equation (54) of this article for analytic calculations of the two examples of nonlinear differential equations of the system solved directly using a digital computer in reference[2,3]. The results showed that the two were entirely consistent. In addition, analytic calculations can also clearly point out the nature of the error of each segment which the solution obtained by computer cannot do.

IV. Conclusion

(1) The regenerative feedback tracking system is a nonlinear multiple input and multiple output system in spherical coordinates. But in the analysis of performance after the system enters the tracking status, it can be changed to a steady linear system of rectangular coordinates or of mixed rectangular and spherical coordinates. Therefore it can be systematically designed and analyzed by the frequency method in the classical theory of cybernetics based on the computational formula obtained in this article.

(2) Intrinsically, the regenerative feedback system is a type of tracking system in rectangular coordinates. Besides the fact that the mismatching error belongs intrinsically to the spherical coordinates system, understanding of all the properties of the system and analysis of the performance must all be considered in rectangular coordinates. Therefore, this type of a

system is completely different from the classical tracking system in spherical coordinates. For example, it can cause the random interference of spherical coordinates to produce mutually intersecting effects, and steady state errors in angular tracking in the spiral sections noted in reference [2] will emerge, etc.

(3) Since the system has been converted to a steady linear system in rectangular coordinates, the conflict between speed and resistance to interference inherent in the steady linear system will not change. Therefore, the problem of optimum design of the system still exists. For example, we can appropriately select the equivalent open domain transfer function defined by equation (56) to design the system into a Wiener filter. But the regenerative feedback system into a Wiener filter. But the regenerative feedback system still eases the conflict between speed and resistance to interference greatly. This is because the rectangular coordinates system is an inertia coordinates system, and the representation of the patterns of motion of the target in inertia coordinates has the narrowest frequency spectrum, therefore we can design the frequency band of the system to be very narrow. This means that good speed can be obtained with a very low open domain gain. This is the fundamental reason that the precision of tracking by the regenerative feedback system is much higher than the classical system.

(4) The main point in the design of the system is the matching condition of the system. Even though complete matching cannot be realized, the mismatching error $\Delta\Psi_D$ should be controlled within the allowable range. To assure good matching by the system, the parameters of the transfer functions K(s) and B(s) must be very stable and precise. Therefore, the deep inverse feedback technique and digital techniques are very important to systems with a high tracking precision. Symmetry in the structure of each channel and designing K(s) as an ideal integrator are not principles that must be followed in designing the system.

[Appendix I] The Problem of Exchanging the Order of Mutiplication of W(s)B(s) and A_A^{-1}

Let $H(s)\triangleq W(s)B(s)$, $f(t)\triangleq A_T^{-1}$, $g(t)\triangleq[E-P(s)]sA_T\Delta\Psi$, then changing the order of multiplication of the operators W(s)B(s) and A_T^{-1} in equation (28) will produce an error

$$\Delta(t)\triangleq H(s)f(t)g(t)-f(t)H(s)g(t) \tag{I-1}$$

Let F(ω) and G(ω) be the Fourier transforms of f(t) and g(t) respectively, then

$$\Delta(t)=\frac{1}{4\pi^2}\left\{\int_{-\infty}^{\infty}H(j\omega)e^{j\omega t}\int_{-\infty}^{\infty}F(\omega-\xi)G(\xi)d\xi d\omega-\int_{-\infty}^{\infty}F(\eta)e^{j\eta t}d\eta\cdot\int_{-\infty}^{\infty}H(j\xi)G(\xi)e^{j\xi t}d\xi\right\}$$

Because H, F, G are all ordinary complex matrices, and H is also a diagonal matrix with the same diagonal elements, we have HF=FH. The above equation becomes

$$\Delta(t)=\frac{1}{4\pi^2}\int_{-\infty}^{\infty}\left\{\int_{-\infty}^{\infty}[H(j\xi+j\eta)-H(j\xi)]F(\eta)e^{j\eta t}d\eta\right\}G(\xi)e^{j\xi t}d\xi \tag{I-2}$$

It can be seen from this that within the range of the frequency band of $F(\eta)$ and $G(\xi)$, $\Delta H(\xi)\triangleq H(j\xi+j\eta)-H(j\xi)$ is very small, thus the $\Delta(t)$ relative to the first term in equation (I-1) is a high order infinitessimal quantity, and therefore the error caused by the exchange of operators can be neglected. The frequency band of $F(\eta)$ of the actual system is smaller than 1 rad/s; the frequency band of $G(\xi)$ is smaller than 10 rad/s, and the frequency band of $H(j\xi)$ is much wider. Therefore, the above conditions can almost always be satisfied in actual engineering. For example, for a mismatched velocity feedback system, we have:

$$K(s)=\frac{k_0}{s(1+Ts)}E, \qquad B(s)=\frac{1}{k_0}E, \qquad H(s)=W(s)B(s)=\frac{E}{k_0+Ts^2}$$

$$H(j\xi)=\frac{E}{k_0-T\xi^2}, \qquad \Delta H(j\xi)\doteq H'(j\xi)j\eta=\frac{2T\xi\eta}{(k_0-T\xi^2)^2}$$

Let $k_0 = 10\cdot 1/s$, $T = 10^{-2}$, then at $\xi = 10$, $\eta = 1$, the relative error caused by the exchange of the above operators is:

$$\left|\frac{\Delta H(j\xi)}{H(j\xi)}\right|=\left|\frac{2T\xi\eta}{k_0-T\xi^2}\right|=2.2\times10^{-4}$$

[Appendix II] Finding the Inverse of the Operator R in Equation (38)

Although we cannot obtain the closed solution of the inverse operator R^{-1}, we can obtain its series expression, and we can prove that this series has a very fast converging rate so that in engineering calculations we can approximately take $R^{-1} = E$. Let $M(s)\triangleq(E+W(s)B(s)C[E-P(s)]s]^{-1}$, $T(t)\triangleq A_r(C-E)A_r^{-1}$,

then equation (38) becomes

$$R = E + M(s)T(t) \tag{II-1}$$

The theory of functional analysis proves[4] that if the norm of the operator $M(s)T(s)$ is smaller than 1, i.e., $\|M(s)T(t)\|<1$, then the inverse R^{-1} of R can be represented by the following series

$$R^{-1}=\sum_{k=0}^{\infty}(-1)^k[M(s)T(t)]^k \tag{II-2}$$

When we take the finite term of the series as an approximation, it becomes

$$R^{-1}\doteq\sum_{k=0}^{n}(-1)^k[M(s)T(t)]^k \tag{II-3}$$

Thus the approximate error is not larger than η:

$$\eta=\frac{\|M(s)T(t)\|^{n+1}}{1-\|M(s)T(t)\|} \tag{II-4}$$

According to the operator theory of functional analysis, we have:

$$\| M(s)T(s) \| \leq \| M(s) \| \cdot \| T(s) \| \tag{II-5}$$

Therefore, the problem of finding R^{-1} becomes a problem of estimating the values of the norms of M(s) and T(t). Because we are concerned about the size of the absolute deviation of each component of the tracking error, it is very natural to discuss this problem in the functional space C(0, ∞). In C(0, ∞), for any vector

$$X(t) = [x_1(t), x_2(t), x_3(t)]^T \tag{II-6}$$

its norm is defined as:

$$\| X \| \triangleq \max_{j \in J} | x_j(t) | \tag{II-7}$$

J represents the index set of each component of X(t) [J=(1,2,3)], and the norm of any linear operator A is defined as:

$$\| A \| \triangleq \sup_{\|X\|=1} \| AX \| \tag{II-8}$$

The symbol "sup" means taking the upper bound of $\|AX\|$ of all $\|X\| = 1$ where $\|X\|=1$ $X \in C(0,\infty)$.

According to the definitive equations (7) and (8) and considering that the effect of M(s) upon the signals is a kind of convolutional operation, it is not difficult to find[4]

$$\| M(s) \| = \max_{i,j} \int_0^\infty | m_i(t) | dt \tag{II-9}$$

$$\| T(t) \| = \max_{i \in I} \sum_{j=1}^{3} | T_{ij}(t) | \tag{II-10}$$

where $m_i(t)$ is the pulse response corresponding to the ith diagonal element of M(s). $T_{ij}(t)$ represents the element at the ith row and the jth column of the number matrix T(t). The norm of the matrix defined by equation (10) is called the ∞--norm. Matrix theory proves[5] that for any two matrices A and B in n-dimensional space, when A is a nonsingular matrix, we have:

$$\| ABA^{-1} \|_\infty = \| B \|_\infty , \tag{II-11}$$

where v is the ∞--norm of the matrix B:

$$v = \| B \|_\infty = \max_{i \in I} \sum_{j=1}^{3} | B_{ij} | \tag{II-12}$$

Let $A = A_T$, $B = C - E$, then besides the two reporting points of $\varepsilon_T = \pm\frac{\pi}{2}$ A_T is nonsingular, and B is a diagonal matrix, thus we can find the p--norm of B:

$$\|B\|_p \triangleq \sup_{\|x\|_p=1} \|BX\|_p \triangleq \sup \frac{\left\{\sum_{i=1}^{n}\left|\sum_{j=1}^{n} B_{ij}x_j\right|^p\right\}^{1/p}}{\left(\sum_{i=1}^{n}|x_i|^p\right)^{1/p}} =$$

$$= \sup \frac{\left(\sum_{i=1}^{n}|B_{ii}x_i|^p\right)^{1/p}}{\left(\sum_{i=1}^{n}|x_i|^p\right)^{1/p}} = \max_{i,j}|B_{ii}| \qquad \text{(II-13)}$$

From equations (10), (11), (13), we obtain

$$\|T(t)\| = \|T(t)\|_p = \|A_T(C-E)A_T^{-1}\|_p = \|C-E\|_p = \max_{i,j}|C_{ii}-1| \qquad \text{(II-14)}$$

Substituting equations (9) and (14) into equations (5), we obtain the estimated value of the norm of the operator M(s)T(t)

$$\|M(s)T(t)\| \leq \max_{i,j}|C_{ii}-1| \cdot \int_0^\infty |m_T(t)|dt \qquad \text{(II-15)}$$

When we consider the actual system, we should always make $W(s)|_{s=j\omega} = 1$ within a very wide range of the frequency band. But in the article, $C_2 = 1$ in equation (48). Referring to the definitive equation for M(s) and equation (48) in the article we know that actually M(s) approximately equals the transfer function of the closed domain of the system with the approximation equation

$$\int_0^\infty |m_T(t)|dt \approx \int_0^\infty m_T(t)dt = 1 \qquad \text{(II-16)}$$

Therefore we have

$$\|M(s)T(t)\| \leq \max_{i,j}|C_{ii}-1| \qquad \text{(II-17)}$$

i.e., the norm of the operator M(s)T(t) is not larger than the imbalance of the structure of the channel. For example, when $|C_{11}-1| \leq 0.05$, if we take $R^{-1} = E$, then the error of approximation $\eta \leq 0.053$. If we take $R^{-1} = E-M(s)T(t)$, then $\eta \leq 2.6 \times 10^{-3}$. It can be seen from this that for smaller deviations due to imbalance (such as $|C_{11} - 1| \leq 0.1$), taking $R^{-1} = E$ as the approximate solution of the inverse operator of R is completely sufficient for engineering calculations.

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FFT To Resolve Acquisition, Tracking in Pulsed-Doppler Radars

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[Article by Tong Kai [4547 6963] of the Beijing Institute of Tracking, Telemetry and Control: "Application of the FFT Technique in Resolving Acquisition and Tracking Problems of Targets With High Velocity and High Acceleration in Pulsed-Doppler Radars"; This article was received in January, 1980, finalized in April 1981]

[Text] Abstract

This article analyzes the ambiguity functions of velocity and acceleration of FFT digital signal processing equipment in a pulsed Doppler precise tracking radar, and it establishes a model for an ambiguity graph of 32 dots. It also applies the methods of number theory to derive a computational formula for the distribution of side lobes under high acceleration, and proposes a method of preprocessing FFT velocity and acceleration by digital matching of the acceleration phase of a target in motion. This type of processing equipment can replace the digital-analog time compressor currently used.

I. Foreword

When a target undergoes high acceleration, acquisition of the target by the velocity tracking circuit has been a relatively difficult problem. To ensure

that the velocimeter circuit acquires the target reliably, the circuit must use differential smoothing of the signals over distance to roughly define the velocity and acceleration, and furthermore, precisely defined corrections of velocity and acceleration are needed so that a certain spectral line near the roughly defined velocity falls in the narrow band of the wave filter and is retained for a sufficient period of time to accomplish acquisition. For this, many radars[1,2,3] use a time compressor system. This system is actually a target velocity and acceleration detection system. Its processing is analog.

The purpose of this article is to explore the output characteristics of the frequency spectrum of FFT digital wave filters when the target undergoes high acceleration, to use methods of numerical computation to find the ambiguity graph of the FFT velocity and acceleration, to use analytic methods to find the patterns of variation of the ambiguity graph, and to propose a plan for preprocessing FFT signals to match the acceleration phase. This means that all-digital equipment can be used to replace the time coupressor to accomplish the functions of processing the target's velocity and acceleration, thus improving the equipment's reliability, precision and total processing time.

II. DFT of the Complex Time Function

The frequency wave form of a coherently pulsed serial echo can be expressed as:

$$u(t) = A(t)\sin[\omega_0 t + \varphi_d(t)] \tag{1}$$

$$\varphi_d(t) = \int \omega_d(t)\,dt = 2\pi \int f_d(t)\,dt \tag{2}$$

where A(t) is the echo envelope, F_r is the repeat frequency, π is the width of the echo pulse (its amplitude is limited), and $f_d(t)$ is the Doppler shift. After the orthogonal phase is detected, the amplitude normalized and digitized, we can obtain:

$$I_k = \cos\varphi_d(t_k) = \cos\varphi_d(kT) = \cos\varphi_d(k)\bullet$$

$$Q_k = \sin\varphi_d(t_k) = \sin\varphi_d(kT) = \sin\varphi_d(k)$$

In the equations, k = -1, 0, 1, ... When using complex time functions to represent them, they can be written as:

$$g(k) = I_k + jQ_k = \cos\varphi_d(k) + j\sin\varphi_d(k) = \exp j\varphi_d(k) \tag{3}$$

• $\Psi_d(k)$ is the abbreviation of $\Psi_d(kT)$.

The discrete Fourier transform of equation (3) is:

$$g(k)=\frac{1}{N}\sum_{n=0}^{N-1}G(n)W^{-nk},\quad k=0,1,\cdots,N-1 \tag{4}$$

$$G(n)=\sum_{k=0}^{N-1}g(k)W^{nk},\quad n=0,1,\cdots,N-1 \tag{5}$$

$$W=\exp(-j2\pi/N) \tag{6}$$

where G(n) is a discrete spectrum, T is the sampling period, N is the number of transformation points. Among them, G(n) can also be regarded as the output of a linear digital wave filter over the time intervals (N-1)T. Its normalized transfer function

$$|H(n)|=\left|\frac{\sin[\pi f_d/(F_r/N)]}{\sin\left[\frac{\pi}{N}\left(\frac{f_d}{F_r/N}-n\right)\right]}\right| \tag{7}$$

III. Ambiguity Function of Velocity and Acceleration

Suppose that the echoes are sampled synchronously over distance. Then the problem of distance mismatching does not exist. Definition: When the velocity and acceleration of a target is mismatched with the nth wave filter, the value of the ambiguity function is the normalized output of that wave filter. To simplify the expression, let n=0, and at this time, the wave filter matches $f_d = 0$, therefore the velocity and acceleration of the target itself are the mismatched amounts of that wave filter. This does not lose the generality in analyzing the problem.

When the target undergoes uniform acceleration, the variation of $f_d(t)$ is illustrated in Figure 1, and we have

$$f_d(t)=f_d+f'_d t,\quad \varphi_d(t)=2\pi[f_d t+(f'_d t^2/2)]+\varphi_0 \tag{8}$$

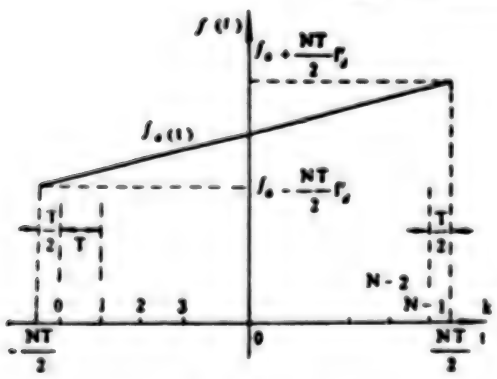

Figure 1. Variation of $f_d(t)$ at uniform acceleration

Substituting $t = [k - (N-1)/2]T$, $k = 0, 1, \ldots\ldots, N-1$ in the above equation and rearranging the terms, we obtain

$$\varphi_d(k) = \frac{2\pi}{N}\left[k\alpha - \frac{(N-1-k)k}{N}\beta\right] + \varphi_0' \tag{9}$$

In equation (9), $2\pi k\alpha/N$ represents the phase change of the average frequency f_d at kT. Here, $\alpha = f_d/(F_r/N)$. It is the normalized value of the frequency which represents the total number of periods within the time NT, and F_r/N represents the unit of resolution of the frequency. The second term represents the phase shift of f_d' at time kT. Here, $\beta = f_d'/(2F_r^2/N^2)$, which is the normalized value of frequency variation. It is one-half the product of time and bandwidth of the linear modulated frequency wave within the length of time from 0 to NT (i.e., f_d' NT· NT/2), where $2F_r^2/N^2$ is the unit of resolution of frequency variation. The third term Ψ_0 is the initial phase after rearranging the terms.

Substituting equation (9) into equations (3) and (5), we can obtain the discrete spectrum of the echo signals when the target has a velocity and acceleration

$$G_{\alpha,\beta}(n) = \sum_{k=0}^{N-1} W^{[-(\alpha-n)k+\beta(N-1-k)k/N]} \tag{10}$$

In the above equation, the initial phase Ψ_0' has been deleted. When $\alpha = \beta = n = 0$, $G_{0,0}(0) = N$. From this, we can write the ambiguity function of the velocity and acceleration:

$$\chi(\alpha, \beta) = \left|\frac{G_{\alpha,\beta}(0)}{G_{0,0}(0)}\right| = \frac{1}{N}\left|\sum_{k=0}^{N-1} W^{(-\alpha k+[\beta(N-1-k)k/N])}\right| \tag{11}$$

We know from Appendix I that because of the symmetry of the function $X(\alpha,\beta)$, the distribution graph of the entire function $X(\alpha,\beta)$ can be obtained if we limit our discussion within the range $0 \leqslant \alpha < N/2$ and $0 \leqslant \beta \leqslant N^2/4$, as shown in Figures 2 and 3. Figure 4 shows a three-dimensional model of the ambiguity graph of velocity and acceleration. In these figures, we have taken N = 32.

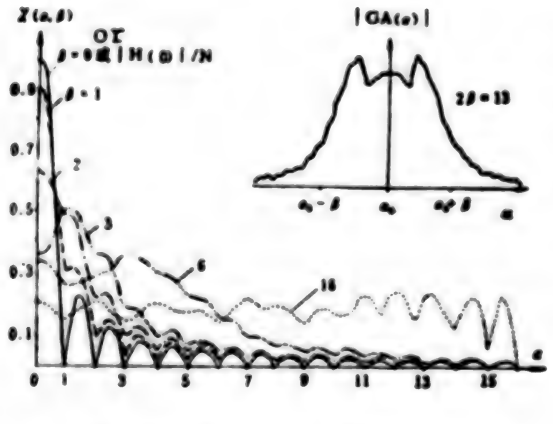

Figure 2. Curve of $X(\alpha,\beta)$-α when = 0,1,2,3,6 and 16.

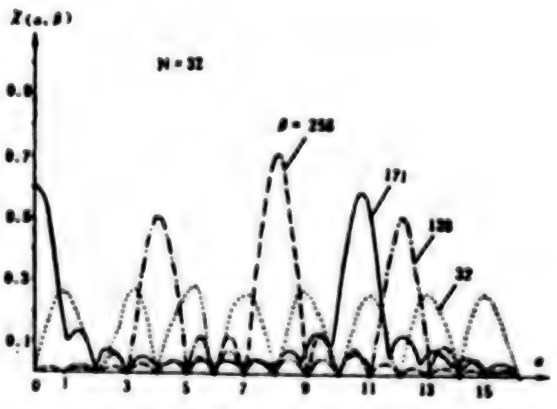

Figure 3. The curve of $X(\alpha,\beta)$-α when = 32, 128, 171 and 256.

图4 速度、加速度立体模糊图模型

Figure 4. Three-dimensional model of the ambiguity graph of velocity and acceleration.

IV. Analysis of the Ambiguity Diagram

When finding the discrete spectrum G(n) of a finitely long discrete time function g(k), we can decompose it into the following steps[6]:

1. Multiplying the continuous function g(t) by the sampling function $\Delta_0(t)$ and the intercept function a(t), we obtain

$$g(k) = g(t)\Delta_0(t)a(t);$$

2. Then we find the continuous frequency spectrum of g(k)

$$G\Delta_0A(f) = GA(f) * \Delta_0(f) = G\Delta_0(f) * A(f) \tag{12}$$

where $\Delta_0(f)$, A(f), GA(f) and $G\Delta_0(f)$ are the frequency spectra of $\Delta_0(t)$, a(t), g(t)a(t), $g(t)\Delta_0(t)$ respectively.

3. Multiplying $G\Delta_0A(f)$ by the frequency spectrum sampling function $\Delta_1(f)$, we have

$$G\Delta_0A(f)\Delta_1(f) = \sum_{n=-\infty}^{\infty} G\Delta_0A\left(\frac{n}{NT}\right)\delta\left[f-\frac{n}{NT}\right]$$

Thus, we obtain the discrete spectrum $G(n) = G\Delta_0A(n/NT)$.

To find $X(\alpha,\beta)$, we first find $G_{\alpha,\beta}(0)$ according to equation (11). The value of $G_{\alpha,\beta}(0)$ is $G\Delta_0A(0)$. To simplify analysis, we interchange $-\alpha$ and n according to equation (10) and obtain $G_{-\eta,\beta}(-\alpha)$, and let $n = 0$. This is equivalent to $f_d = 0$. The α in these equations should be a continuous parameter, therefore,

$$G_{\alpha,\beta}(0) = G_{\alpha,\beta}(-\alpha) = G\Delta_0A(-\alpha)|_{\alpha=\alpha} \tag{13}$$

where $\alpha = f/(F_r/N)$, $\alpha_0 = f_d/(F_r/N)$. This is slightly different in meaning than the previous use of α to represent $f_d/(F_r/N)$, please take note.

In the following we will seek an analytic solution:

1. When the product of time and bandwidth is small, the condition is $2\beta < N$. This is equivalent to $f_d'NT < F_r$. Because the value of β is small, the frequency bandwidth of $g(t) \cdot a(t)$ is narrower, therefore, when using F_r for sampling, mixing and overlapping of the main frequency spectra will not occur. Thus, using the method of finding the g(t)a(t) frequency spectrum first is more convenient. g(t)a(t) is a time function of a linear modulated frequency pulse. Its frequency variation is as shown in Figure 1, the largest value of its pulse amplitude is 1, its pulse width is NT, thus its frequency spectrum is

$$GA(f)=\int_{-NT/2}^{NT/2} \exp[j2\pi(f_d t + f_d' t^2/2 - ft]dt$$

Solving this integral numerically yields[7]:

$$|GA(\alpha)| = \frac{NT}{2\sqrt{\beta}}\{[C(x_1)+C(x_2)]^2+[S(x_1)+S(x_2)]^2\}^{1/2} \tag{14}$$

In the equation, C(x) and S(x) are Fresnel integrals,
$x_1=\sqrt{\beta}(\beta+\alpha-\alpha_0)/\beta$, $x_2=\sqrt{\beta}(\beta-\alpha+\alpha_0)/\beta$.

Reference [7] also gives the wave form of GA(f). To compare it with the wave form of $\beta = 6$, we have specially introduced into Figure 2 the wave form of $2\beta = 13$ (the width of the passing band is 2β, its central value is α_0).

According to equation (12) and $\Delta_0(f)$, we can obtain:

$$G\Delta_0 A(f)=\frac{1}{T}\sum_{i=-\infty}^{\infty} GA(f-iF_r)\exp[j\pi i(N-1)]$$

According to equation (13), and using α to represent f, we obtain

$$|G_{\alpha,\beta}(0)| = \frac{1}{T}\left|\sum_{i=-\infty}^{\infty} GA(iN-\alpha)\exp[j\pi i(N-1)]\right|_{\alpha=0}$$

Because the passing band represented by the normalized GA(α) is about 2β, and to avoid mixing and overlapping of the main frequency spectra, analysis is carried out only for $\beta < N/2$. Thus from equation (11) we obtain:

$$\chi(\alpha,\beta)\simeq\frac{1}{NT}\sum_{i=-\infty}^{\infty}|GA(iN-\alpha)|_{\alpha=0} \tag{15}$$

When β increases to N from N/2, the main frequency spectra mix and overlap. At this time $X(\alpha,\beta)$ shows wave motion characteristics and gradually extends from the α high end (i.e. at $\alpha = N/2$) towards the low end.

2. When the Product of the Time and Bandwidth Is Large

Because the ambiguity graph shows visible wave motion characteristics when the product of time and bandwidth is large ($2\beta > N$), and even produces high side lobes, therefore, a clear understanding of the amplitude of the peak values of the side lobes and the patterns of distribution has an important meaning. For this, we first seek a way to find the discrete spectral line of $G\Delta_0(f)$, then it will be more convenient to compute $G\Delta_0(f) * A(f)$ according to equation (12). From equations (8) and (9) we can find:

$$\begin{aligned} G\Delta_0(f) &= \int_{-\infty}^{\infty} g(t)\,\Delta_0(t)\exp[-j2\pi ft]\,dt \\ &= \sum_{k=-\infty}^{\infty} \exp j2\pi\{(f_d - f)kT + [k^2T^2 - (N-1)kT^2]f_d'/2 + f_d''\}\, G\Delta_0(-f)\Big|_{f_d=0} \\ G\Delta_0(-f)\Big|_{f_d=0} &= \sum_{k=-\infty}^{\infty} \exp j2\pi\left[\left(f - \frac{N-1}{2}f_d'T\right)kT + \frac{1}{2}f_d''k^2T^2\right] \end{aligned} \tag{16}$$

According to the further derivation of equation (16) shown in Appendix II, we can obtain the following: When $\beta = pN^2/q$, $(p, q) = 1$, and let $q = 2^{\ell}q_1$ (q_1 is an odd number), then we have:

$$|G\Delta_0(-\alpha)|_{\alpha_d=0} = \begin{cases} \dfrac{1}{\sqrt{qT}} \displaystyle\sum_{i=-\infty}^{\infty} \sum_{u=0}^{q-1} \delta\left[\alpha - \left(i + \frac{u}{q}\right)N\right], & \text{Let } \ell = 0,\ q = q \\ \dfrac{1}{\sqrt{q/2}\,T} \displaystyle\sum_{i=-\infty}^{\infty} \sum_{u=1,3,5,\ldots}^{q-1} \delta\left[\alpha - \left(i + \frac{u}{q}\right)N\right], & \text{If } \ell = 1,\ N \text{ is an odd number} \\ & \text{Or, } \ell > 1,\ N \text{ is an even number} \\ \dfrac{1}{\sqrt{q/2}\,T} \displaystyle\sum_{i=-\infty}^{\infty} \sum_{u=0,2,4,\ldots}^{q-2} \delta\left[\alpha - \left(i + \frac{u}{q}\right)N\right], & \text{If } \ell = 1,\ N \text{ is an even number} \\ & \text{Or, } \ell > 1,\ N \text{ is an odd number} \end{cases} \tag{17}$$

In the equations, α is the value of normalized f. In addition, the Fourier transform of the known intercept function a(t) is:

$$A(\alpha) = NT\frac{\sin 2\pi\alpha}{2\pi\alpha} \tag{18}$$

From equations (13) and (12) we have:

$$G_{\alpha,\beta}(0) = \int_{-\infty}^{\infty} A(-\tau)[G\Delta_0(-\alpha+\tau)|_{\alpha_d=0}]\,d(-\tau)$$

and we consider

$$\begin{aligned} \int_{-\infty}^{\infty} A(-\tau)\delta\left[\alpha - \left(i + \frac{u}{q}\right)N - \tau\right]d(-\tau) &= A\left[\alpha - \left(i + \frac{u}{q}\right)N\right] \\ &= NT\frac{\sin 2\pi\left[\alpha - \left(i + \frac{u}{q}\right)N\right]}{2\pi\left[\alpha - \left(i + \frac{u}{q}\right)N\right]} \end{aligned}$$

From this and according to equation(11), we can write the approximation formula for the ambiguity function when the main frequency spectra $A\{a-[i+(u/q)]N\}$ do not mutually overlap:

$$\chi(a,\beta)\simeq \begin{cases} \frac{1}{\sqrt{q}}\sum_{i=-\infty}^{\infty}\sum_{u=0}^{q-1}\left|\frac{1}{NT}A\left[a-\left(i+\frac{u}{q}\right)N\right]\right|, \\ \frac{1}{\sqrt{q/2}}\sum_{i=-\infty}^{\infty}\sum_{u=1,3,\ldots}^{q-1}\left|\frac{1}{NT}A\left[a-\left(i+\frac{u}{q}\right)N\right]\right|, \\ \frac{1}{\sqrt{q/2}}\sum_{i=-\infty}^{\infty}\sum_{u=0,2,\ldots}^{q-1}\left|\frac{1}{NT}A\left[a-\left(i+\frac{u}{q}\right)N\right]\right|, \end{cases} \quad (19)$$

If $\ell=0$, $q=q$

If $\ell=1$, N is an odd number Or $\ell>1$, N is an even number

If $\ell=1$, N is an even number Or $\ell>1$, N is an odd number

Table 1 gives the amplitudes of the peak values of X (α,β) for each value of β calculated according to equation(17) with N=32 and the positional α values. They coincide completely with the model of the curve of the ambiguity graph computed by the digital computer.

V. Application

Equation (10) shows that transformation matches the phase of the sampled repeat signals first and then their sum is found. Therefore, there will always be one integral value close to α so that $|\alpha - n| \leqslant 1/2$. At this time, the nth wave filter and the signal are basically matched. The amplitude of normalized output (when $\beta = 0$) will be greater than 0.6368 (-3.92dB). Therefore it is not difficult to estimate the approximate value of α of the target from this n value. This kind of digital matching can be generalized without difficulty to situations that have acceleration. At this time, equation (10) is generalized to:

$$\begin{aligned} G(m,n) &= \sum_{k=0}^{N-1}\exp j2\pi\left[(\alpha-n)\frac{k}{N}-(\beta-m)\frac{(N-1-k)k}{N^2}\right] \\ &= \sum_{k=0}^{N-1}B(k)W^{nk}M^{m(N-1-k)k} \end{aligned} \quad (20)$$

In the equation, $W = \exp(-j2\pi/N)$, $M = \exp(j2\pi/N^2)$. When m takes a certain integral value, we can always make $|\beta - m| \leqslant 1/2$. If the velocity is matched at this time, i.e., $|\alpha - n| \leqslant 1/2$, then the normalized output of the (n,m) filter will not be much smaller than 0.6368. When m takes only even numbers, $|\beta - m| \leqslant 1$ (still taking $|\alpha - n| \leqslant 1/2$), the normalized output of the (n,m) wave filter will be larger than 0.6340(-3.96dB). W^{nk}, $M^{m(N-1-k)k}$ are called the phase matching factors of velocity and acceleration. Their introduction will not only enable the wave filter to match the velocity of the target, they can also be used to find the approximate acceleration of the target.

Table 1. Distribution of Peak Values of $X(\alpha,\beta)$ When N=32

t	q	Peak value	$\alpha = uN/q$	$\beta = pN^t/q, (p,q)=1$
	1	1.000	0.	1024(缺0),
	3	0.577	0,10.67,21.33,	341.33,682.67,
	5	0.447	0,6.40,12.80,19.20,25.60,	204.80,409.60,614.40,819.20,
	7	0.378	0,4.57,9.14,13.71,18.29,22.86,27.43,	146.29,292.57,438.86,585.14,731.43,877.71,
$=0$	9	0.333	0,3.56,7.11,10.67,14.22,17.78,21.33, 24.89,28.44,	113.78,227.56,455.11,568.89,796.44,910.22,
u takes integers	11	0.302	0,2.91,5.82,8.73,11.64,14.55,17.45, 20.36,23.27,26.18,29.09,	93.09,186.18,279.27,272.36,465.45,558.55, 651.64,744.73,837.82,930.91,
	13	0.277	0,2.46,4.92,7.39,9.85,12.31,14.77, 17.23,19.69,22.15,24.62,27.08,29.54,	78.77,157.54,236.31,315.08,393.85,472.62, 551.38,630.15,708.92,787.69,866.46,945.23,
	15	0.258	0,2.13,4.26,6.40,8.53,10.67,12.80, 14.93,17.07,19.20,21.33,23.47,25.60, 27.73,29.87,	68.27,136.53,273.07,477.87,546.13,750.93, 887.47,955.73,
	2	1.000	0,	512,
	6	0.577	0,10.67,21.33,	170.67,853.33,
	10	0.447	0,6.40,12.80,19.20,25.60,	102.40,307.20,716.80,921.60,
	14	0.378	0,4.57,9.14,13.71,18.29,22.86,27.43,	73.14,219.43,365.71,658.29,804.57,950.86,
	18	0.333	0,3.56,7.11,10.67,14.22,17.78,21.33, 24.89,28.44,	56.89,284.44,398.22,625.78,739.56,967.11,
$=1$ u takes even numbers	22	0.302	0,2.91,5.82,8.73,11.64,14.55,17.45, 20.36,23.27,26.18,29.09,	46.55,139.64,232.73,325.82,418.91,605.09, 698.18,791.27,884.36,977.45,
	26	0.277	0,2.46,4.92,7.39,9.85,12.31,14.77, 17.23,19.69,22.15,24.62,27.08,29.54,	39.38,118.15,196.92,275.69,354.46,433.23, 590.77,669.54,748.31,827.08,905.85,984.62,
	30	0.258	0,2.13,4.26,6.40,8.53,10.67,12.80, 14.93,17.07,19.20,21.33,23.47,25.60, 27.73,29.87,	34.13,238.93,375.47,443.73,580.27,648.53, 785.07,989.87,
	4	0.707	8,24,	256,768,
	8	0.500	4,12,20,28,	128,384,640,896,
>1	12	0.408	2,67,8,13.33,18.67,24,29.33,	85.33,426.67,597.33,938.67
u takes	16	0.354	2,6,10,14,18,22,26,30,	64,192,320,448,576,704,832,960,
odd	20	0.316	1.60,4.80,8,11.20,14.40,17.60,20.80,	51.20,153.60,358.40,460.80,563.20,665.60,
numbers			24,27.20,30.40,	870.40,972.80,
	24	0.289	1.33,4.6.67,9.33,12,14.67,17.33,20, 22.67,25.33,28,30.67,	42.67,213.33,298.67,469.33,554.67,725.33, 810.67,981.33,
>1	28	0.267	1.14,3.43,5.71,8,10.29,12.57,14.86,	36.57,109.71,182.86,329.14,402.29,475.43,
u takes			17.14,19.43,21.71,24,26.29,28.57,30.86,	548.57,621.71,694.86,841.14,914.29,987.43,
odd	32	0.250	1,3,5,7,9,11,13,15,17,19,21,23,25,27,	32,96,160,224,288,352,416,480,544,608,672,
numbers			29,31,	736,800,864,928,992

Because we have assumed that the target is in uniform acceleration and also because the value of f_d is the value at k=(N-1)/2, thus to find the value of f_d at time k=N, we should extrapolate acceleration. The compensating value of extrapolation is $(N+1)T\ f_d'/2 = m(N+1)F_r/N^2$. But we can also calculate the velocity at time t = NT. At this time, we have:

$$f_d(t)=f_d+f_d'(t-NT),$$
$$\varphi_d(t)=2\pi[f_d t+(t^2-2NTt)f_d'/2]+\varphi_0$$

When $t = kT$, $\varphi_d(k)=2\pi\{\alpha k/N-[\beta(2N-k)k/N^2]\}+\varphi_0$.

Therefore equation (2) becomes:

$$G(n,m)=\sum_{k=0}^{N-1}g(k)W^{nk}M^{m(2N-k)k} \tag{21}$$

The actual method of finding G(n,m) is to multiply the signal g(k) by $M^{m(2N-k)k}$ first to find $g_m'(k) = g(k)M^{m(2N-k)k}$, then subject $g_m'(k)$ to FFT to find G(n,m). FFT to find $g_{m+1}'(k)$ and to find G(n,m) can be carried out simultaneously.

We will now present a preliminary discussion of the question of choosing the values for N and m as followings: The choice of the value of N is determined by the degree of resolution of velocity measurements. The degree of resolution of velocity is $\delta f_d = F_r/N$, or $\delta R' = \lambda F_r/2N$, where $\delta R'$ is the resolution of velocity, λ is the wavelength. To facilitate treatment of N, we take the power of 2. N=32 is sufficient. When $F_r = 320$ Hz, $\lambda = 0.05$m, thus $\delta R' = 0.25$ m/s, while the unit of resolution of acceleration is $\delta f_d' = 2F_r^2/N^2$, or $\delta R'' = \lambda F_r^2/N^2$ when m takes integral values. Here, $\delta R''$ is the resolution of acceleration. Under the above parameters, $\delta R'' = 5\ m/s^2$. The greatest value of m is limited by the side lobes of the ambiguity graph of velocity and acceleration. Therefore this article has found the pattern of distribution of peak value positions to make it easy to determine the range and the threshold value that m can reach.

When a side lobe smaller than -6dB is taken, and when we consider the possibility that acceleration may be either positive or negative, we realize that $|m|$ should be smaller than $N^2/12$. When N=32, $|m|$ must not be greater than 85, i.e., R''_{max} should be within $\pm\lambda F_r^2/12 = \pm 425\ m/s^2$. Therefore, when the target's acceleration is larger than this value, it is necessary to use the value of acceleration smoothed out by the pulsed telemetric signal to roughly define the target's acceleration.

VI. Conclusion

This article has analzyed the ambiguity graph of velocity and acceleration of a target and has established a model of the ambiguity graph using 32 sampling points. It has given the amplitude of the peak values of every side lobe and the position of distribution without loss. It has thus provided a reference for further analysis and engineering design in the future.

The article has also proposed an all digital method of matching the phase of acceleration while simultaneously matching the velocity of a target. This will further the work of digitizing signal processing.

Appendix I

Now let us discuss the symmetry of the function $X(\alpha,\beta)$, where α, β, are not necessarily integers. Due to the limitation of this article, the proof has been omitted.

Property 1: $X(\alpha,\beta)$ has multiple values, i.e.,

$$X(\alpha,\beta)=X[\alpha(\mathrm{mod}N),\beta(\mathrm{mod}N^2)] \tag{I-1}$$

Property 2: $X(\alpha,\beta)$ is symmetric about the origin, i.e.,

$$X(\alpha,\beta)=X(-\alpha,-\beta) \tag{I-2}$$

Property 3: $X(\alpha,\beta)$ is symmetric about the axis $\alpha = 0$ and $\alpha = N/2$, i.e.,

$$X(\alpha,\beta)=X(-\alpha,\beta), \quad X[(N/2)-\alpha,\beta]=X[(N/2)+\alpha,\beta] \tag{I-3}$$

Property 4: $X(\alpha,\beta)$ is symmetric about the axis $\beta = 0$ and $\beta = N^2/2$, i.e.,

$$X(\alpha,\beta)=X(\alpha,-\beta), \quad X[\alpha,(N^2/2)-\beta]=X[\alpha,(N^2/2)+\beta] \tag{I-4}$$

Property 5: When N is an odd number, $X(\alpha,\beta)$ is symmetric about the point $(\alpha = N/4, \beta = N^2/4)$, and when N is an even number, $X(\alpha,\beta)$ is symmetric about the axis $\beta = N^2/4$, i.e.:

$$X[(N/4)-\alpha,(N^2/4)-\beta]=X[(N/4)+\alpha,(N^2/4)+\beta], \quad N \text{ is odd} \tag{I-5A}$$

$$X[\alpha,(N^2/4)+\beta]=X[\alpha,(N^2/4)-\beta], \quad N \text{ is even} \tag{I-5B}$$

According to the above properties, we can study the function $X(\alpha,\beta)$ within $0 \leq \alpha \leq N/2$, $0 \leq \beta \leq N^2/4$.

Appendix II

When the product of time and bandwidth is large, we can derive the relation of $GA_0(-f)\,|\,f_{d=0}$ which produces a discrete frequency spectrum. We know

$$GA_0(-f)\Big|_{f_d=0}=\sum_{k=-\infty}^{\infty}\exp j2\pi\left[\left(f-\frac{N-1}{2}f_r'T\right)kT+\frac{1}{2}f_r'k^2T^2\right] \tag{16}$$

Let $k = rq + x$, where q is any positive integer, $x = 0,1,\ldots,q-1$; $r=0, \pm1, \pm2, \ldots, \pm\infty$. Substituting into the above equation we obtain:

$$G\Delta_s(-f)\Big|_{f_d=0}=\sum_{x=0}^{q-1}\exp j2\pi\left[\left(f-\frac{N-1}{2}f_d'T\right)Tx+\frac{1}{2}f_d'T^2x^2\right]$$

$$\cdot\sum_{r=-\infty}^{\infty}\exp j2\pi\left\{fr_qT+[-(N-1)+r_q+2x]\frac{f_d'}{2}qT^2r\right\}$$

To find the sum of the latter terms of the above equation and to form a discrete frequency spectrum, the main condition is that $[-(N-1)+r_q+2x]f_d'qT^2r/2$ be an integer within the chosen values of r and x. Therefore, we should have $f_d' = 2pF_r^2/q$. This is equivalent to $\beta = pN^2/q$, where p, q are relative prime integers, i.e., (p, q) = 1. At this time, the above equation becomes:

$$G\Delta_s(-f)\Big|_{f_d=0}=\frac{1}{qT}\sum_{r=-\infty}^{\infty}\delta\left(f-\frac{xF_r}{q}\right)\sum_{x=0}^{q-1}\exp j\frac{2\pi}{q}\{[x-p(N-1)]x+px^2\}$$

If we let $z = iq + u$, $u = 0, 1, \ldots, q-1$; $i = 0, \pm1, \pm2, \ldots, \pm\infty$ and substitute these into the above equation, we obtain:

$$G\Delta_s(-f)\Big|_{f_d=0}=\frac{1}{qT}\sum_{r=-\infty}^{\infty}\sum_{u=0}^{q-1}\delta\left[f-\left(i+\frac{u}{q}\right)F_r\right]$$

$$\cdot\sum_{x=0}^{q-1}\exp j\frac{2\pi}{q}\{[u-p(N-1)]x+px^2\} \qquad \text{(II-1)}$$

To find the final summation in equation (II-1), let $s[q, f(x)]=\sum_{x=0}^{q-1}\exp j\frac{2\pi}{q}\cdot f(x)$, while $f(x) = px^2 + [u-p(N-1)]x$, where $[p, u-p(N-1), q] = 1$. The q can be any nonzero integer, and then let $q=q_1q_2$, q_1 is an odd number, $q_2= 2^\ell$, ℓ is a nonnegative integer. According to Theorem 2 on page 197 in reference [10]: If $(q_1, q_2) = 1$, then

$$S(q_1q_2, f(x)) = S(q_1, f(q_2x)/q_1)S(q_2, f(q_1x)/q_2) \qquad \text{(II-2)}$$

where

$$|S(q_1, f(q_2x)/q_1|=\left|\sum_{x=0}^{q_1-1}\exp j\frac{2\pi}{q_1}\{p(2^\ell x)^2+[u-p(N-1)]2^\ell x\}/2^\ell\right|$$

$$=\left|\sum_{x=0}^{q_1-1}\exp j\frac{2\pi p2^\ell}{q_1}\left[x+\frac{u-p(N-1)+cq_1}{q2^{\ell+1}}\right]^2\right| \qquad \text{(II-3)}$$

In the equation, c should be an integer. The condition that $[u-p(N-1)+cq_1]/p2^{\ell+1}$ has an integral solution is $(q_1, p2^{\ell+1})\,|\,[u-p(N-1)]$*1 (i.e., q_1, $p2^{\ell+1}$) is exactly divisible. Because q_1 is an odd number, (p,q) = 1, i.e., $(p,q_1)=1$, therefore, $(q_1, p2^{\ell+1})=1$, while u-p(N-1) is an integer, the above condition is completely satisfied, thus $[u-p(N-1)+cq_1]/p2^{\ell+1}$, can be an integer by appropriately selecting c. Therefore, when x passes through any complete residue system, when $\mathrm{mod}q_1$, $x+[u-p(N-1)+cq_1]/p2^{\ell+1}$ also passes through a complete residue system, $\mathrm{mod}q_1$, and the result of equation (II-3) becomes

$$|S[q_1, f(q_2x)/q_1]| = \sqrt{q_1} \quad \text{*2} \qquad \text{(II-4)}$$

*1 In reference [10], p 11, Theorem 1 of "the solution of the indeterminate equation of the first degree."

*2 In reference [10], p 178, "Gaussian sum" and pp 128-183, Theorem 6.

In the second term in equation (II-2) we have

$$|S[q_1, f(q_1,x)/q_1]| = \left|\sum_{x=0}^{E} \exp j\frac{2\pi pq_1}{2^l}\left[x+\frac{u-p(N-1)+c2^l}{2pq_1}\right]^2\right| \qquad \text{(II-5)}$$

In the equation, $E = 2^l-1$, c is an integer, and the condition for $[u-p(N-1)+c2^l]/2pq_1$ to have an integral solution is $(2^l, 2pq_1)\,|\,[u-p(N-1)]$. Because $(p,q) = 1$, therefore $(p,2^l) = 1$, q_1 is an odd number, and thus when l is a positive number $(2^l, 2pq_1) = 2$. At this time, we should differentiate between two situations:

1) When $u-p(N-1)$ is an even number (i.e., N is an even number, u should be odd, and when N is odd, u should be even), $[u-p(N-1)+c2^l]/2pq_1$ is an integer when the value of c is appropriately selected. Therefore, when x passes through a complete residue system, $\bmod 2^l$, $x+[u-p(N-1)+C2^l]/2pq_1$ also passes through a complete residue system, $\bmod 2^l$, thus the results of equation (II-5) can be represented as [10]*3:

$$|S[q_1, f(q_1,x)/q_1]| = \begin{cases} 0 & \text{If } l=1 \\ 2^{(l+1)/2} & l>1 \end{cases} \qquad \text{(II-6)}$$

2) When $u-p(N-1)$ is an odd number (i.e., when N is an even number, u should be even, and when N is an odd number, u should be odd), then equation (II-6) is no longer valid. At this time, the value is calculated by the following equation: When $l=1$,

$$|S[q_1, f(q_1,x)/q_1]| = \left|\sum_{x=0}^{1} \exp j\frac{2\pi}{2}\{pq_1x^2+[u-p(N-1)]x\}\right| = 2$$

(2) When $l > 1$,

$$|S[q_1, f(q_1,x)/q_1]| = \left|\sum_{x=0}^{E} \exp j\frac{2\pi}{2^l}\{pq_1x^2+[u-p(N-1)]x\}\right|$$

$$= \left|\sum_{x=0}^{E'} \{1+\exp j\pi[u-p(N-1)]\} \exp j\frac{2\pi}{2^l}\{pq_1x^2+[u-p(N-1)]x\}\right| = 0$$

In the equation, $E' = 2^{l-1}$, $E' = 2^{l-1}-1$. Therefore, when $u-p(N-1)$ is an odd number, we have

$$|S[q_1, f(q_1,x)/q_1]| = \begin{cases} 2^{(l+1)/2} = 2, & \text{When } l=1 \\ 0, & l > 1 \end{cases} \qquad \text{(II-7)}$$

*3 In reference [10], p 183, Theorem 7.

We substitute the results of equations (II-2) - (II-7) into equation (II-1). When $\beta = pN^2/q$, $(p,q) = 1$, $(p,q) = 1$, let $q=2^{\ell}q_1$, q_1 is an odd number, thus we have:

$$|G_{\Delta,(-\alpha)}|_{\alpha=\frac{n}{q}} = \begin{cases} \frac{1}{\sqrt{qT}} \sum_{i=-\infty}^{\infty} \sum_{n=0}^{q-1} \delta\left[\alpha-\left(i+\frac{n}{q}\right)N\right], & \text{If } \ell=0,\ q=q_1 \\ \frac{1}{\sqrt{q/2\,T}} \sum_{i=-\infty}^{\infty} \sum_{n=1,3,5,\ldots}^{q-1} \delta\left[\alpha-\left(i+\frac{n}{q}\right)N\right], & \text{If } \ell=1,\ N \text{ is an odd number} \\ & \text{Or } \ell>1,\ N \text{ is an even number} \\ \frac{1}{\sqrt{q/2\,T}} \sum_{i=-\infty}^{\infty} \sum_{n=1,3,5,\ldots}^{q-1} \delta\left[\alpha-\left(i+\frac{n}{q}\right)N\right], & \text{If } \ell=1,\ N \text{ is an even number} \\ & \text{Or } \ell>1,\ N \text{ is an odd number} \end{cases} \quad \text{(II-8)}$$

In the equation, f has already been normalized to α, and F_r should be normalized to N.

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CHINA'S BIG WEATHER BALLOONS PERFORM VARIETY OF SCIENTIFIC CHORES

Beijing BEIJING WANBAO in Chinese 23 Sep 81 p 2

[Article: "China's High-Altitude Weather Balloons"]

[Text] At mid-day of 12 September, a shimmering object floated through the sky over Beijing, drifting slowly from east to west and evoking wide-spread curiosity among the city's residents. Was it a "UFO"? No, it was a 30,000-cubic-meter (as big as an 80-meter-high, 14-story highrise apartment building) high-altitude scientific research balloon launched by the Chinese Academy of Sciences and related units. Its altitude was 34,000 meters as it floated some 40 kilometers south of Beijing.

Today, high-altitude scientific research balloons are the crucial tools China needs to conduct experiments and observations dealing with stratospheric and mid-atmospheric physics, high-energy physics, cosmic ray and high-altitude physics, infrared astronomy, sun-earth space physics and remote sensing. In recent years, many countries with advanced space sciences have made much use of these balloons to conduct observations and research. They are more cost-effective than either satellites or aircraft and are more flexible for conducting experiments and convenient; they are now an integral part of the organic make-up of space sciences.

China's high-altitude scientific experiment balloons consist of the following main components: The balloon itself (1), the recovery chute (2), the suspended gondola (3), and the signal equipment (4). The bag is made of high-quality polyethylene film to withstand the buffeting encountered at high altitudes and temperatures of -70 degrees. At the same time, after being filled with hydrogen, it must carry a payload into the upper atmosphere, supporting the entire load. The gondola (usually in excess of 100 kilograms) is packed with various instruments and equipment--it may be considered a kind of airborne floating observatory or "control station," to be used as a link between the surface of the earth and the sky, conducting probes of the atmosphere and space. It carries out orders from the ground control center--a part of the key link of balloon technology. The beacon equipment is special purpose gear to help fix the position of the gondola during recovery. After the separation of the gondola from the gasbag, the recovery chute brakes the descent, assuring a safe landing for the instrument package. In addition, the interior of the gondola is provided with protective layers to keep the instruments aboard from being damaged when the gondola makes its landing. A radio sounding device is provided along with cut-off devices and other auxiliary equipment.

High-altitude balloon engineering and technology are in their initial stages in China and to date, although there are only several dozen balloons for different experimental requirements, already certain probe data have been collected. We believe that in the not-too-distant future these balloons will shoulder greater roles in production, national defense, scientific experiments and other scientific endeavors and that there will be many more high-altitude balloons drifting in the vast skies of north China.

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MILITARY TECHNOLOGY TRANSFERRED TO CIVILIAN USE

Problems, Tasks

Beijing GUANGMING RIBAO in Chinese 22 Jan 82 p 1

[Article by commentator of this paper: "Do The Work of Transferring Military Technology to Civilian Use Well"]

[Text] In developing the national economy, especially during the period of economic readjustment, we must emphasize and exert efforts to transfer the technology of the military industry to civilian use well so that it can actively serve the national economy and we can coordinate the development of national defense and economic buildup.

For the past 2 years, leading comrades and scientific and technical personnel of the national defense scientific and technological sector have begun to emphasize this work that benefits both the military and the civilian sectors, and they have obtained definite results and accumulated some experience. But, at present, the form of transfer of the technology of the military industry to civilian use is still limited to the production of civilian consumer goods by military factories, frequently "competing with the civilian factories," and the technical superiority of the military factory system cannot be developed. We believe there is even more important work that needs to be done. For example, first, we must use some advanced scientific technologies of the military industry system to serve the national economy according to the plan and step by step. These technologies include aviation, nuclear energy, telemetry, remote control, remote sensing, automatic control, high strength heat resistant structural materials, etc. Second, we must fully develop the use of the specialized testing facilities of the military industrial system, such as wind tunnels, vibration environment facilities, radiation environment facilities, overload environment facilities, so that they can serve civilian units. Third, we must gradually popularize and apply the experience gained in the development and management of large systems of the military to large scale projects in economic construction. Fourth, we must develop the potential of the intellectual resources of some specific specialities in the military to provide counseling service for civilian enterprises. In addition, it is not a matter of simply transferring from the "military" to the "civilian" sector; there are many facets of civilian technology, especially production technology, which must also be

transferred to military production. The two are mutually interchangeable and develop together.

In transferring military industrial technology to civilian use, we believe the following three problems amust be solved. First, the technology must be suitable. Military industrial technology, especially some advanced pioneer technologies, when popularized and applied in the civilian sectors, cannot simply be copied. There is a process of transplanting and reorganizing. Certain scientific and technical forces must be invested. Second, the cost must be reduced. This is a key problem in transferring military industrial technology to civilian use at present. Technology with too high a cost does not have any competitiveness in the civilian market. It must be suitable, and it must be inexpensive. Therefore, we cannot just "compete" with certain "hot items" on the domestic market. The military and civilian sectors must cooperate to continue to develop new products suitable for marketing, and we must open up international markets. Third, we must handle the relationship between exchange and secrecy well. We should say, there are only a very small number of technologies that belong strictly to military technology and that are national secrets which cannot be applied in the civilian sector. Whether in the military or the civilian sector, it is necessary to carry out full internal exchange and cooperate extensively. National secrets must also be safeguarded within a definite scope. The problem of mutual concealment of technology because of competition must be gradually solved through compensatory technological transfer, technological and economic contracts, and establishment of patent laws and policies and legal measures.

The transfer of military industrial technology to civilian use must also emphasize the transfer of scientific and technical abilities and the flow of scientific and technical talent. The common experience of some advanced regions that have used scientific techniques to stimulate the economy and that have implemented technical transfer is treasuring talent and allowing each to develop his own talent. Within the scope of the whole nation, the structure of scientific and technical teams should be readjusted gradually and in an organized manner according to plan during the course of economic readjustment and readjustment of science and technology. But at present, it is unsuitable and not possible to advocate "free movement" of talent. Talent needs to move about, but talent cannot be allowed to move freely. This is a difficulty. The only effective way to overcome this difficulty is to allow a "directional flow of knowledge." The so-called "directional flow of knowledge," simply speaking, is to absorb and "borrow" various scientific and technical capabilities and knowledge from other regions, other units, and society to contribute towards developing a locality's science, technology, and economy and to develop one's own unit within a definite period with purpose, with organization, and with leadership according to the specific needs of one's own region, own department, own profession, own unit, without involving personnel reorganization and population movement. The departments and units of the national economy can select the best and the needed, and concentrate and organize various forces in joint ventures to promote the transfer of science and technology, to fill the deficiency of talent through "directional flow of knowledge." "Directional flow of knowledge" has been proven in practice to suit the civilian population and it should be suitable

between the military and the civilian sectors under definite conditions. It is also beneficial to promoting the transfer of military industry technology to civilian use. Its organization can be in many forms. For example: civilian units can invite scientific and technical experts of the military sector to serve concurrently as advisors. Concerned departments can organize scientific and technical personnel in the military to lecture and send them on academic leave for short periods to civilian units. Exchange of technology between the military and the civilian sector can be strengthened. Scientific and technical exchange activities should be launched. A mutually fitting relationship of mutual learning and mutual help should be established. The boundary line between the military and the civilian sectors must be broken. A joint venture of scientific research-production-utilization as a "whole" and as "one chain" can be organized, etc. In this way, we must carry out several practical and feasible policy measures, for example: cooperation between the military and the civilian sectors, financial management of joint ventures (source of capital, share of investment, distribution of profits), rational rules on living expenses, benefits and salary of guest experts, etc.

To transfer military industrial technology well, we must strengthen organization and leadership. There must be corresponding organizations and agencies to serve as channels for the transfer of military industrial technology. All of the scientific research units of the "military" and "civilian" sectors and the leadership at each level and the science and technology management departments must strengthen mutual contact, cooperate extremely, exert efforts to coordinate the development of national defense and economic build-up and jointly serve the development of the national economy.

Remote Technology Transferred

Beijing GUANGMING RIBAO in Chinese 22 Jan 82 p 1

[Article by Song Guangli [1345 1684 4409] and Xu Jiuwu [1776 0046 2976]: "National Defense Scientific Research Sector Emphasizes the Transfer of Military Technology, The Three Technologies of Telemetry, Remote Control and Remote Sensing Are Popularized in Civilian Sectors and Results Have Been Achieved"]

[Text] The scientific research units subordinate to the National Defense scientific research sector have emphasized the transfer of military technology. They have transplanted and popularized the three technologies (of telemetry, remote control, remote sensing) used in the products of the military industry among civilian sectors and preliminary achievements have been realized. This was learned at the national industrial telemetry and remote control conference held not long ago in Beijing. The conference was sponsored by the special committee on telemetry, remote control, and remote sensing of the China Automation Society.

To adapt to the needs of readjusting the national economy, national defense research units took the initiative to readjust the direction of their work with the prerequisite that they complete their military scientific research tasks first. Then they went to every sector of the national economy to

conduct broad and in-depth investigations and studies, utilized such measures as cooperative efforts, technological exchange and direct research and development of new products to hasten the progress of transferring the techniques of telemetry, remote control and remote sensing to civilian use. At present, these have already been applied in industry, agriculture, medicine, physical education, urban public services, and they have shown a broad future for application.

In industry, a certain research institute of the national defense science research sector used telemetry and remote control techniques in oil exploitation to help Dagang Oil Field establish a monitoring and control system. The operator only has to issue orders from the control consol at the central station to automatically control the operations of oil extraction, transportation and adding water in the oil wells. Also, the amount of extraction of oil and such parameters as temperature and pressure in the oil wells can be accurately calculated any time, and thus the modernized management level of the oil field has been improved.

In medical treatment and public health, a certain research institute used telemetric techniques to monitor and protect the heart, and test produced a 6-channel telemetric heart beat monitor and protector. The patient only has to wear two button-sized electrodes and a microscopic emitter and his electrocardiogram will be clearly shown on the screen at the monitoring and protection center via radio transmission. When the heart beat is abnormal, the monitor can also sound an alarm signal. Preliminary trial use shows this instrument can simultaneously monitor tachycardia, bradycardia, arrhythmia, arrest of ventricular activities of the heart and premature ventricular waves of the heart of sick patients in real time.

In physical education, a certain research institute and the Physical Education Science Research Institute of the National Physical Education Committee developed a telemetric system to measure electrical activity of the muscles of athletes. This has contributed to the improvement of the level of training in our nation's physical education and sports. How to find the critical fatigue stage of an athlete is a key link in training. For a long time, because of a lack of advanced equipment, this work has always relied on the experience of the trainer and the judgment of some instruments. After using the telemetric system to measure the electrical activity of the muscles, the athlete only has to wear a sensor and an emitter which are as large as the finger nails on his body. The electrical signals of the muscles of each part of the body can be shown on the screen of an oscilloscope via radio transmission. This has provided scientific reference for accurately judging whether the athlete's physical qualities are being developed normally, the state of fatigue and recovery of the muscles, variation of nerve functions, and the best time for exerting force and intensity. The famous high jump athlete and trainer Ni Zhiqin [0242 1807 2953] personally used this instrument to conduct experiments and expressed satisfaction over the results of testing.

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COMPUTER SIMULATION OF INTEGRATED CIRCUITS DESCRIBED

Beijing DIANZI KEXUE JISHU [ELECTRONIC SCIENCE AND TECHNOLOGY] in Chinese No 1, 1982 pp 2-6

[Article by Ruan Gang [7086 0474]: "Computer Simulation Models for Integrated Circuits"]

[Text] Computer simulation of integrated circuits is an important step in achieving complete computer-assisted design of integrated circuits. A number of foreign companies and universities are engaged in this research; among them the SUPREM (Stanford University Circuit Engineering Model) program developed by the Integrated Circuit Laboratory of Stanford University is relatively well-known.[1-3] This program is a computer simulation of the most typical IC manufacture technology and it is a rather powerful program. The program takes the IC manufacture conditions as the input and provides output such as the one-dimensional distribution of impurity in silicon and parameters such as junction depth, thin film resistance, and threshold voltage of the MOS transistor. It can simulate a one-step as well as a multi-step manufacturing process, and it can also simulate the entire engineering procedure of a complete circuit. It simulates the distribution of B, P, As, Sb and Al impurities in Si and SiO_2, ion implantation, gaseous and solid chemical predeposition of the surface, driven diffusion, oxidation, epitaxy, erosion, and oxide deposition at low temperature. The format of the input parameters is simple and straightforward; the impurity distribution output may be displayed in graphic form and the minimum depth interval can be 100 A in tabulated output.

In China, the LSI laboratory of Fudan University has modified the IBM0-03 version of the SUPREM-2 program and transferred it to the NEC ACOS-4S/300 system imported from Japan by the Shanghai Foreign Trade Bureau. The modified version is known as the NEC FD 01 version of SUPREM-2. In this article we shall describe the models used in the SUPREM-2 program.

Ion Implantation Model

1. Simple Symmetric Gaussian Distribution

The simple symmetric Gaussian distribution is a crude model for impurity implantation in IC manufacturing, but the execution of this simple model is

retained in the SUPREM program. Based on user provided implantation parameters R_p, σ_p and implant quantity Q, the program does a simple symmetric Gaussian distribution.

In computing R_p and σ_p in the LSS theory, it is assumed that the bulk concentration N(y) of the implanted impurity follows a simple symmetric Gaussian distribution

$$N(y)=\frac{N_s}{\sqrt{2\pi}\sigma_p}\exp\left[-\frac{1}{2}\left(\frac{y-R_p}{\sigma_p}\right)^2\right] \qquad (1)$$

where N_s is the total impurity in units of atoms/cm^2. The implant quantity Q is related to N_s by the following equation

$$Q=\int_0^\infty N(y)dy=\frac{N_s}{\sqrt{2\pi}\sigma_p}\int_0^\infty \exp\left[-\frac{1}{2}\left(\frac{y-R_p}{\sigma_p}\right)^2\right]dy \qquad (2)$$

Let P_y be the peak concentration, then we have

$$P_p=\frac{N_s}{\sqrt{2\pi}\sigma_p}=Q\Big/\int_0^\infty \exp\left[-\frac{1}{2}\left(\frac{y-R_p}{\sigma_p}\right)^2\right]dy \qquad (3)$$

$$N(y)=P_p\exp\left[-\frac{1}{2}\left(\frac{y-R_p}{\sigma_p}\right)^2\right] \qquad (4)$$

From known values of R_p, σ_p and Q, N(y) can be computed according to equations (3) and (4).

2. Two Connected Half Gaussian Distributions

When the user supplies the energy and quantity of implantation and the element being implanted is As or P, then the program carries out the modeling of two connected half Gaussian distributions. The two half Gaussian distributions have their own standard deviations σ_1 and σ_2 (with respect to R_m). R_m is known as the model range (also known as the form range or the connection moment). Figure 1 shows schematically the two connected half Gaussian distributions. When the concentration of the implanted impurity ions on the two sides are $N_1(y)$ and $N_2(y)$ respectively, then,

$$N_1(y)=P_p\exp[-(y-R_m)^2/2\sigma_1^2] \quad 0\le y\le R_m \qquad (5)$$
$$N_2(y)=P_p\exp[-(y-R_m)^2/2\sigma_2^2] \quad R_m<y\le\infty \qquad (6)$$

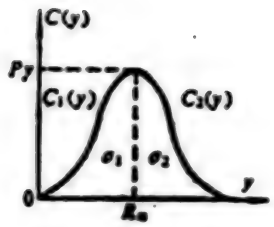

Fig. 1. Two connected half Gaussian distributions.

where P_y is related to the quantity Q of implanted ions by the following equation

$$P_y = Q/[Q(\sigma_1, R_m, 0, R_m) + Q(\sigma_2, R_m, R_m, \infty)] \qquad (7)$$

and $Q(\sigma, R, a, b)$ is the implanted ion quantity normalized by P_y.

$$Q(\sigma, R, a, b) = \int_a^b \exp[-(y-R)^2/2\sigma^2]\,dy \qquad (8)$$

In SUPREM-2, parameters σ_1, σ_2 and R_m are determined from the known implantation energy by looking up the table and by interpolation.

3. Modified Pearson IV Distribution Model

When boron ions are being implanted, the program executes the modified Pearson IV distribution model based on user supplied implantation energy and dosage.

It has been pointed out that the distribution of the implanted boron in amorphous silicon before annealing may be described by the standard Pearson IV distribution model. Formulas for the standard Pearson IV distribution model are

$$N(y) = N_0 e^{f(y)} \qquad (9)$$

$$f(y) = \frac{1}{2b_2}\ln|b_0 + b_1 X_0 + b_2 X_0^2| - \frac{(b_1/b_2 + 2a)}{(4b_2b_0 - b_1^2)^{1/2}}\tan^{-1}\left[\frac{2b_2X_0 + b_1}{(4b_2b_0 - b_1^2)^{1/2}}\right] \qquad (10)$$

Parameters in equation (10) can be expressed as follows

$$\left.\begin{aligned} X_s &= (y - R_s)/\sigma, \\ a &= -\gamma_1(\beta_1 + 3)/A \\ b_0 &= -(4\beta_1 - 3\gamma_1^2)/A \\ b_1 &= a \\ b_2 &= -(2\beta_1 - 3\gamma_1^2 - 6)/A \end{aligned}\right\} \qquad (11)$$

In equation (11), $$A = 10\beta_1 - 12\gamma_1^2 - 18 \qquad (12)$$

N_o in equation (9) can be found from the equation below

$$N_s = Q/\int e^{f(y)}\,dy \qquad (13)$$

It can be seen from equations (9) to (13) that the standard Pearson IV distribution is determined by σ_p, R_p, γ_1, β_1 and Q.

Figure 2 shows the experimental data of implanted boron distribution and computed curves of the Pearson IV distribution model. As shown in the illustration, there is good agreement between Pearson IV distribution and the experimentally obtained boron distribution from the surface to slightly over the distribution peak. There is considerable deviation from the Pearson IV distribution in describing the tail. Experimentally measured tail distribution is exponential, and the exponential tail distribution is produced by random scattering of the boron ions in the direction of the channel. In order to describe the experimental results more closely, the authors of SUPREM-2 used an empirically modified Pearson IV distribution model. In this model an exponential tail is added to the standard Pearson IV distribution, and a fixed characteristic length (0.045 micrometer) independent of dopant energy and crystallographic orientation is chosen. The exponential tail is attached to the shoulder of the standard Pearson IV distribution at the point where the concentration has dropped to 50 percent of the peak value. After attaching the tail, the distribution of the implanted ion dosage must be renormalized. The modified Pearson IV distribution agrees very well with the typical experimental result, as shown in Figure 2.

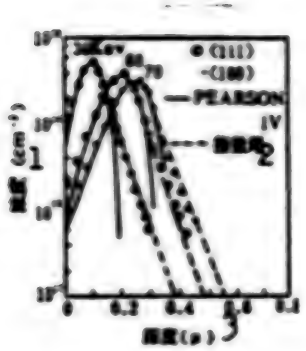

Fig. 2. Asymmetric distribution of implanted boron ion in arbitrary direction in 111 and 100 Si.
Dosage is $10^{13}cm^{-2}$.

Key: 1. Concentration
2. Exponential tail
3. Depth

4. Range Correction in the Presence of SiO_2 Layer on Si Surface

Since the stopping powers of Si and SiO_2 are slightly different, the model range R_m in the connected half Gaussian distribution and the average projection range R_p in the modified Pearson IV distribution should both be corrected when a layer of SiO_2 exists on the Si surface--the so-called SiO_2-Si dual substrate. In the SUPREM-2 program, the following two equations are used for this correction

$$R'_{msi}=R_{msi}+(1-R_{msi}/R_{mox})Z_{ox} \quad (14)$$

$$R'_{psi}=R_{psi}+(1-R_{psi}/R_{pox})Z_{ox} \quad (15)$$

In equation (14) R_{msi} and R_{mox} are respectively the model ranges for a single Si substrate and for impurity implantation in SiO_2. R'_{msi} represents the model range of implanting impurity into the SiO_2-Si dual substrate, i.e., the corrected model range or the effective model range. Similarly, in equation (15) R_{psi} and R_{pox} are respectively the average projection ranges of implanting impurity into a single Si substrate and into SiO_2 and R'_{psi} represents the average projection range of impurity implantation in the SiO_2-Si dual substrate, i.e., the corrected average projection range or the effective average projection range. Z_{ox} is the thickness of the SiO_2 layer.

Impurity Mobility During Annealing

1. Diffusion Flow Model

At any given point P, the diffusion flow of impurity $F_D(y)$ is described by Fick's first law as the gradient of the product of diffusivity and concentration at that point

$$F_D(y) = -\frac{d}{dy}[D(y)\cdot C(y)] \qquad (16)$$

where D(y) is the coefficient of diffusion of the impurity. Under the assumption of diffusing as a single state, there is no generation or loss in the material and the on-dimensional continuitv equation, i.e., the conservation equation can be written as

$$\frac{dQ(y_1,y_2)}{dt} = -[F_D(y_2)-F_D(y_1)] \qquad (17)$$

For homogeneous diffusion, Fick's second law may be obtained by substituting (17) and (19) into (20) and differentiating with respect to y

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial y^2} \qquad (18)$$

In general Fick's second law holds for low impurity concentration. When impurity concentration is equal to or greater than the intrinsic carrier concentration $n_i(T)$ in the semiconductor at annealing temperature T, Fick's second law is no longer applicable. Figure 3 shows the relationship between n_i and temperature T; it is used as the Quesheng [4972 4164] value of $n_i(T)$ in SUPREM-2. In addition, when other high concentration impurities are present in silicon, equation (18) is not applicable for the diffusing impurity even at low concentration. We shall use the term intrinsic silicon when all the impurity concentrations in silicon are lower than $n_i(T)$ at annealing temperature T and the term nonintrinsic silicon when concentrations are higher than $n_i(T)$ of silicon at annealing temperature T.

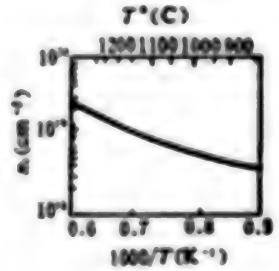

Fig. 3. Temperature dependence of intrinsic carrier concentration n_i in silicon.

Diffusion coefficient for nonintrinsic silicon. For most impurities the diffusion coefficient in nonintrinsic silicon is approximately 10 to 20 times greater than that in intrinsic silicon. It is generally believed that diffusion in nonintrinsic silicon is a result of the interaction between impurity and charged point defects in silicon. Except phosphorous, we assume the diffusivity of the impurity atom is determined only by neutral and singly charged defect state

$$D = D_i(1+\beta f_v)/(1+\beta) \qquad (19)$$

where D_i is the observable intrinsic diffusivity, $f_v = n/n_i$ (for donors) and $f_v = n_i/n$ (for acceptors). Under the intrinsic condition, $f_v = 1$ and $D = D_i$. For the nonintrinsic condition

$$D^- = D_i \frac{1}{1+\beta}, \quad D^x = D_i \frac{\beta}{1+\beta} \qquad (20)$$

where $\beta = D^v / D^x$ is the ratio of the diffusivity D^v due to charged vacancy and the diffusivity D^x due to neutral vacancy. Figure 4 shows the relationship between normalized diffusivity D/D^i and f_v. Recommended values of β (also the Quesheng value used in SUPREM-2) are 3 for boron, 100 for arsenic, and phosphorus is described by a completely different model. The β value for other impurities is not yet known and is taken to be 1.

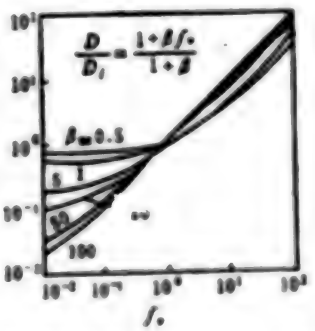

Fig. 4. Normalized diffusivity as a function of normalized carrier concentration for different β values.

Effects of other high concentration impurities on diffusion. When different impurity atoms exist in silicon, they interact with each other. Figure 5 shows the calculated effect of high concentration on the distribution of boron. In SUPREM-2 the modeling of this interaction is directly through the computation of equation (19). In the example of Figure 5, the decrease of boron diffusion in the heavily doped region is because f_v (boron) = $\frac{n_i}{n} \to 0$. Outside the boundary of As distribution, the drop of boron distribution is due to the rapid spatial variation of boron diffusivity.

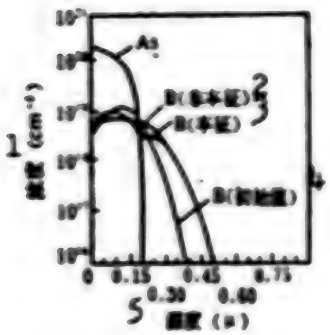

Fig. 5. Interpretation of the effect of high concentration As on the redistribution of boron.

Key: 1. Concentration
2. Nonintrinsic
3. Intrinsic
4. Initial value
5. Depth

Model of phosphorus diffusion. SUPREM-2 uses the phosphorus diffusive mobility model[4] proposed by Fair and Tsai in 1977. In bipolar transistor technology, a cusp-shaped P distribution curve and base propagation were observed in the diffusion of the heavily doped emitter region. In this model, it is believed that these "irregular" effects are due to the increase in vacancy concentration in silicon arising from the dissociation of phosphorus flowing from the surface into the bulk and the charge vacancy pairs. A typical distribution of high concentration phosphorus is shown in Figure 6.

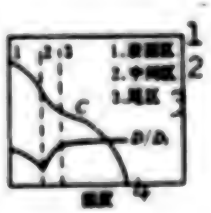

Fig. 6. Typical distribution of phosphorus impurity and diffusivity according to the model of Fair and Tsai.

Key:
1. Surface region
2. Intermediate region
3. Tail region
4. Depth

In the surface region, the diffusion of phosphorus is assumed to be due to the interaction of phosphorus and the neutral or paired charge vacancies in forming $P^+V^=$. The diffusivity in this region is given by

$$D = f_s[D^+ + D^-(n/n_i)^2] \quad (21)$$

where n is free electron concentration and can be computed from the relation[5] between total phosphorus concentration C and free electron concentration n

$$C = n + 2.04 \times 10^{-41} n^3 \quad (22)$$

From (21) and (22), diffusivity in this region decreases monotonically as shown in Figure 6. The end of the surface region is assumed to be located at the point where the Fermi level has dropped to 0.11 eV below the bottom of the conduction band, or at the energy level of the doubly ionized vacancy state. Here the electron concentration n_e is given by

$$n_i(T) = 4.85 \times 10^{15} \exp(-0.39 eV/KT) \quad (23)$$

In the tail region the diffusivity is strengthened with respect to the intrinsic diffusivity. This is because the dissociation of $P^+V^=$ leads to a supersaturation of vacancies in the silicon point lattice. Diffusivity in the tail region is given by the following empirical equation:

$$D_{Tail} = f_s\left\{ D^+ + D^- \frac{n_s^2}{n_i^2 n_i} \left[1 + \exp\left(\frac{0.3 eV}{KT}\right)\right]\right\} \quad (24)$$

where n_s is the surface electron concentration. As can be seen from equation (24), the tail diffusivity depends strongly on the surface concentration of phosphorus. After the model predicted supersaturation of vacancy defects in the bulk, it was later proven that, under the region of high phosphorus surface concentration, any other impurity element in the silicon point lattice also shows diffusivity enhancement, roughly equal to the enhancement in phosphorus. In SUPREM-2, the enhancement factor f_{enh} is computed with the following equation

$$f_{enh} = D_{Tail}/f_s D^+ \quad (25)$$

In the presence of phosphorus, the diffusivity of any other impurity is obtained by multiplying the corresponding f_{enh} and the intrinsic diffusivity D^x of that impurity. The model handled in this manner explains the base propagation effect and predicts the diffusivity enhancement of other elements (for example, As or Sb that can form a buried collector region in the manufacture of bipolar transistors); this point has been verified experimentally.

In the case of heavy doping, an intermediate region is observed between the surface and the tail region and diffusivity in the intermediate region increases with $(n_i/n)^2$. In SUPREM-2, this empirical rule is used in the

determination of the beginning of the tail region. The diffusivity computed at the end of the surface region where $n = n_e$ is multiplied by $(n_i/n)^2$, which increases with depth, and the beginning of the tail region corresponds to the depth at which the diffusivity has increased to D_{tail}.

From equation (24), the phosphorus diffusivity in the tail region increases monotonically with increasing surface concentration. But the tail diffusivity actually decreases when surface concentration exceeds $3\sim4 \times 10^{20}$ cm^{-3}. This may be attributed to the narrowing of the bandgap due to stress on the point lattice introduced by the high phosphorus concentration. In SUPREM-2 this stress effect is described by an increase in the intransic carrier concentration n_i:

$$n_i = n_i \text{ (stress free) } \exp(-\Delta E_g/KT) \qquad (26)$$

Here Δ Eg is the bandgap narrowing due to stress, given by

$$\Delta E_g = -1.5\times10^{-21}(C_{TS} - 3\times10^{18}cm^{-3})eV \qquad (27)$$

In equation (27), C_{TS} is the total surface concentration of phosphorus. Of course, n_e must be increased by the same amount as well. Figure 7 shows the computed phosphorus distribution with and without ΔE_g. This result demonstrated the importance of the stress consideration.

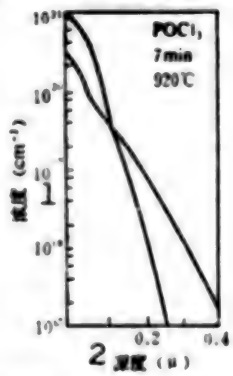

Fig. 7. Two different computed surface concentration of phosphorus distributions. The stress model of silicon leads to a slower diffusion for the higher surface concentration distribution.

Key:
1. Concentration
2. Depth

SUPREM-2 also takes into account an additional stress effect that influences the diffusion of implanted phosphorus distribution. At high doses, a further

reduction of the diffusivity is observed, possibly due to the permanent randomness of the point matrix generated in the process of ion implantation. For ion implanted phosphorus, the additional bandgap narrowing can be computed from the following equation:

$$\Delta E_g = -2.3\times10^{-4}(Q_p)^{1/3}\ eV \qquad (28)$$

where Q_p is the dosage of phosphorus atom.

2. Oxidation Enhanced Diffusion

The diffusion of boron and phosphorus is enhanced when the surface of silicon is oxidized. This phenomenon of oxidation enhanced diffusion (OED) is generally attributed to an increase of point defects in silicon due to oxidation. Hu[6] proposed a model that relates OED to the growth of OSF (oxidation stacking fault). For boron in silicon in an oxidizing environment SUPREM-2 assumes a temperature dependent and time independent OED. For phosphorus in a dry oxygen environment a fixed enhancement factor of 1.8 is assumed and the value is assumed to be 3.3 for the case of wet oxygen. Moreover, temperature and time dependent OED has been observed for other common impurities in silicon.

3. Interface Flow

Although the chemical reaction actually taking place at the interface is not very well understood, the flow of the impurity atoms through the interface can usually be described by a first order dynamics model:

$$F_s = h(C_1 - C_2/m_{eg}) \qquad (29)$$

where F_s is dopant flow, taken to be positive when the flow is from region 1 to 2, C_1 and C_2 are respectively the impurity concentrations on the region 1 side and on the region 2 side at the interface. Figure 8 depicts an SiO_2/Si interface. m_{eg} is the equilibrium segregation coefficient in region $1\sim2$ of the impurity under discussion. The definition of m_{eg} is

$$m_{eg} = C_{2e}/C_{1e} \qquad (30)$$

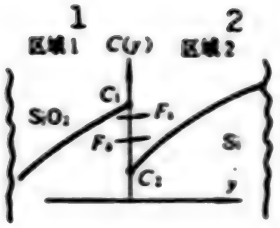

Fig. 8. SiO_2/Si interface.

Key:

1. Region 1
2. Region 2

In equation (30), C_{10} and C_{20} are respectively the equilibrium impurity concentration on the region 1 side and on the region 2 side of the interface. The factor h in (29) is the surface mass transfer coefficient and has the units of velocity.

For a moving interface there is also a motion-induced interface flow caused by unequal impurity concentration. This flow F_b is represented by

$$F_b = -V_{ox}(C_1 - \alpha C_2) \qquad (31)$$

where $V_{OX} = dZ_{OX}/dt$ is the oxidation growth rate, α is the ratio of oxidized silicon thickness to the oxide layer thickness (equal to 0.44). Generally F_b and F_s compete with each other. When $h \gg V_{ox}$, then $C_2 \rightarrow m_{eg}C_1$ and equilibrium segregation dominates. In SUPREM-2, h is arbitrarily chosen to be 0.1 μm/min and $h \gg V_{ox}$ is obviously satisfied.

4. Generation and Loss Mechanism--Model of Arsenic Diffusion

Almost all the impurity dopants can exist in silicon in more than one state, especially at high concentration. A typical situation is that one state is interstitial and mobile and the other state is some form of precipitant or cluster and immobile. The exchange between these two states can be described by the generation and loss term in the mobile impurity continuity equation (16). SUPREM-2 includes a model for the clustering of arsenic. Due to the lack of a suitable model, the effects of clustering and precipitation on the migration of other atoms are ignored. The chemical reaction for arsenic is assumed to be

$$mAs \underset{K_d}{\overset{K_c}{\rightleftharpoons}} As_m \qquad (32)$$

where m is number of atoms in the cluster, K_c and K_d are respectively the rate constants for clustering and for declustering. The concentration of atomic clusters is defined as

$$C_c = C_T - C \qquad (33)$$

where C_T is the total concentration, C is the interstitial concentration and the conservation equation of C_c is

$$\frac{\partial C_c}{\partial t} = mK_c C^m - K_d C_c = l - g \qquad (34)$$

where l and g are respectively the loss term and the generation term in (16). Equilibrium cluster coefficient K_e is defined as

$$K_e = \left(\frac{K_c}{K_d}\right)^{1/m} \qquad (35)$$

Equation (34) can be rewritten as

$$\frac{\partial C_c}{\partial t} = K_d[m(K_e C)^m - C_c] = l - g \qquad (36)$$

Equation (36) is used to describe the thermal diffusion of atoms in silicon. The value m = 4 is most consistent with recently observed results. The declustering rate is taken to be that proposed by Schwenker et al[6]. Under equilibrium (i.e., $\partial C_c/\partial t = 0$) and for m = 4, equation (36) becomes

$$\frac{C_T}{C} = 1 + 4K_e^4 C^3 \qquad (37)$$

Figure 9 is a graphic display of equation (37). As can be seen, clustering limits the maximum concentration of interstitials, and this limiting effect is a function of annealing temperature

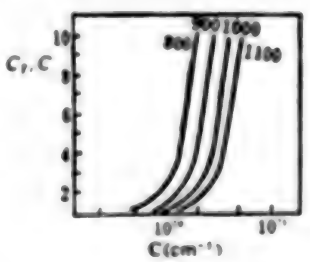

Fig. 9. Normalized total As concentration as a function of interstitial As concentration at different temperatures under equilibrium. Curves are obtained from the cluster model.

Thermal Oxidation

In SUPREM-2 the rate of growth of SiO_2 on Si is given by the familiar equation

$$Z_{ox}^2 + AZ_{ox} = B(t + \tau) \qquad (38)$$

where Z_{ox} is the thickness of the oxide layer, t is time, and A and B are related to the linear growth coefficient K_L, the parabolic growth coefficient K_p and the normalized O_2 partial pressure P_{O_2}

$$A = P_{O_2} K_p / K_L \qquad (39)$$

$$B = P_{O_2} K_p \qquad (40)$$

Parameter τ depends on the initial oxide layer thickness,

$$\tau = \frac{Z_{ox}^2(t=0) + A Z_{ox}(t=0)}{B} \qquad (41)$$

At low dopant concentration K_L and K_p are only dependent upon the crystal orientation of Si and the oxidation atmosphere and they are simple activation functions of temperature.

The oxidation rate of Si increases at high surface concentration regions such as the drain and the source of MOST and the emitter of bipolar transistors. It was discovered by Ho et al[7] that the linear rate coefficient indicative of the surface reaction rate increases substantially and the parabolic rate coefficient indicative of the O_2 diffusion through SiO_2 only increases moderately. These increases slow down as temperature increases. SUPREM-2 uses the model of Ho and Plummer in the quantitative description of the relationship between the enhancement of K_L and K_p and the surface dopant concentration. The basic concept here is that the oxidation rate of Si depends on the concentration of lattice vacancy, which in turn is closely related to the concentration of dopant atom, as we have discussed in the diffusion flow model.

According th this model, the linear rate coefficient can be written as

$$K_L = K_L^i [1 + \gamma (C^T - 1)] \qquad (42)$$

where K_L^i is the intrinsic (i.e., low concentration) linear rate coefficient and γ is an experimentally determined parameter, given by

$$\gamma = 2.62 \times 10^3 \exp\left[-\frac{1.10\text{eV}}{KT}\right] \qquad (43)$$

Here C^T is the normalized total concentration of vacancy, given by

$$C^T = \frac{1 + C^+\left(\frac{n}{n_i}\right) + C^-\left(\frac{n}{n_i}\right) + C^=\left(\frac{n}{n_i}\right)^2}{1 + C^+ + C^- + C^=} \qquad (44)$$

where

$$C^+ = \exp[(E^+ - E_i)/KT], \quad E^+ = 0.35\text{eV}$$

$$C^- = \exp[(E_i - E^-)/KT], \quad E^- = E_i - 0.57\text{eV}$$

$$C^= = \exp[(2E_i - E^- - E^=)/KT], \quad E^= = E_i - 0.11\text{eV}$$

From the expressions of the normalized intrinsic concentrations of vacancies in three different charge states, we can see that each charged state of the vacancy has its corresponding energy state in the silicon bandgap. The temperature dependence of the bandgap E_g and intrinsic energy level E_i are

$$E_g(T) = 1.17 - 4.73\times10^{-4}[T^2/(T+636)]\,eV \quad (45)$$

$$E_i(T) = E_g/2 - KT/4 \quad (46)$$

For the n type dopant, the enhancement of the parabolic oxidation rate is given by

$$K_p = K_p^i(1+\delta C_T^{2/3}) \quad (47)$$

where

$$\delta = 9.63\times10^{-15}\exp\frac{2.83}{KT}\,eV \quad (48)$$

K_p^i is the intrinsic parabolic rate and C_T is the total atomic concentration of the n type dopant.

Because of the distribution of the diffusion and segregation, the surface concentration of the impurity changes during oxidation and the enhancement of K_L and K_p are usually time dependent. For this reason, SUPREM-2 does not use the classical oxide growth equation

$$\Delta Z_{ox} = \left[\frac{1}{2} - (2Z_{ox}+A) + \sqrt{2(Z_{ox}+A)^2 + 4B\Delta t}\right] \quad (49)$$

where Δt is a small time increment. When the simulation time is chosen to be within Δt, due to the redistribution of impurities in silicon, the values of A and B are obtained from the surface impurity concentration in each Δt and the corresponding increment in oxide thickness ΔZ_{ox} is obtained from these A and B values.

Silicon Epitaxy

The epitaxial growth model used in SUPREM-2 is shown in Figure 10.

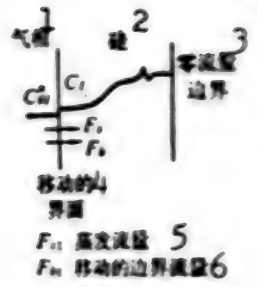

Fig. 10. Impurity redistribution model for epitaxial growth of Si.

Key:

1. Gas phase
2. Silicon
3. Zero flow interface
4. Mobile interface
5. Evaporation flow
6. Mobile interface flow

It is assumed that the gas in the container has a single uniform dopant of an equivalent concentration C^*_{gI} (a fictitious concentration equal to the dopant concentration necessary for uniform epitaxy). The actual situation of the gas phase is not considered in SUPREM-2. Figure 10 shows that there are two flows F_b and F_d at the solid-gas interface. F_s is the "evaporation" flow

$$F_s = h(KC^*_{gI} - C_I) \qquad (50)$$

where h is the evaporation coefficient of the impurity, as mentioned in the discussion on interface flow. We shall define that, except for the joining of the interface by direct movement, all impurity flows between the solid phase and the gaseous phase are evaporation flows. C_I is the impurity concentration at the solid surface and K is the surface equilibrium segregation coefficient, defined by

$$K = C_{I0}/C^*_{gI0} \qquad (51)$$

where C^*_{gI0} and C_{I0} are respectively the gaseous phase surface impurity concentration and the solid surface impurity concentration at equilibrium.

The term F_b represents the flow due to interface movement, similar to the oxidation situation, F_b is given by

$$F_b = V(C^*_{gI} - C_I) \qquad (52)$$

where V is the boundary velocity (growth rate).

The calculation of diffusion flow of impurities in the solid has already been discussed earlier.

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PROBLEMS IN SEMICONDUCTOR STORAGE DESIGN DISCUSSED

Beijing DIANZI KEXUE JISHU [ELECTRONIC SCIENCE AND TECHNOLOGY] in Chinese No 1, 1982 pp 7-11

[Article by Zhang Wujian [1728 0523 0256] of the Sichuan Electronic Equipment Company: "Some Considerations in Designing Semiconductor Storage Systems"]

[Text] Introduction

Beginning in the mid-1970's, along with the rapid development of the semiconductor integrated circuit, semiconductor storage has gradually become the main technique for large computers in foreign countries. In China, due to the limitations in the development of the semiconductor industry, this innovation process in storage technology was delayed by about 5 years. Semiconductor storage has had a profound impact on the performance-price ratio, software design, versatility of terminal facility and microcomputer application. Semiconductor storage has the advantages of a high degree of integration, low power consumption, small volume, and convenience in usage and maintenance and is gradually replacing magnetic core storage. How to adapt to this technological change and how to design and develop storage systems with attractive performance-price ratios based on the characteristics of semiconductor storage are important issues before us.

From the viewpoint of storage system development, semiconductor storage has the following features:

1. Test Patterns Are Complex

Semiconductor storages are highly integrated; the storage unit, driver, decoder and readout amplification circuits are all on the same chip, so it is pattern sensitive. In order to test the functions of semiconductor storage effectively, several tens of test patterns have been designed. To this end, testing equipment capable of checking a multitude of patterns must be developed, and considerable time will be needed to complete a total functional test. Therefore, the testing cost (including labor) is a significant portion of the development cost of the entire semiconductor system.

2. Peripheral Circuit of the System Is Correspondingly Simple

The semiconductor storage itself already has some driving, decoding and readout amplification ability--the new 64K dynamic MOS RAM even has refresh control on the same chip--and the further development of "intelligent storage" even gives the storage device computational and control ability. This makes the peripheral circuits of the system correspondingly simple: ordinary integrated logic circuits can be used.

3. High Density Assembly Can Be Easily Realized

Both the semiconductor storage and the peripheral circuit are assembled from components. Therefore, system assembly can be simplified to rational division of plug-in boards and layout of these boards. This has not only simplified the technical design but has also made high density assembly easy to realize.

When compared with the magnetic core storage system, semiconductor storage also has the advantage of a short development period.

Some Considerations in Designing Semiconductor Storage Systems

1. Organization Methods

Along with meeting demands for higher speed and greater capacity of the computer main storage, the development of the main storage structure goes from single storage to multiple storage. The emergence of semiconductor storage has provided favorable conditions for a multiple storage system. In a multi-storage system, there are three basic organization configurations (see Figure 1): (1) Multiple storage time-shared access-in this configuration, all the storage units share the same input and output interface and main line; it is suited for the case where the processor is required to do batched high-speed retrieval of numbers. In order to resolve the dilemma of high-speed access of the processor and the storage period, a number of buffer registers are installed in the input-output interface, thereby prolonging the number-retrieval time of the random access. Its advantage is the high utilization rate of peripheral interface circuitry and the high rate of signal transmission on the main line. (2) Multiple storage real-time access--here each storage has its own input and output interface and main line; this scheme is suited for the case where a number of processors and request sources are accessing the mainframe storage. It reduces the random access time of number retrieval from the main storage, but it requires a large number of interfaces and main lines and the design of the storage control network is also relatively complicated. (3) Multiple storage, hybrid access--each storage operates in a real-time access mode, but each storage unit is subdivided into a number of modules which operate in a time-shared mode. This scheme is a compromise: it not only satisfies the requirement of multiple request sources having simultaneous access to the main storage but also improves the rate of signal transmission on the main line and the utilization rate of the interface circuitry and eases the cycle time pressure on the main storage.

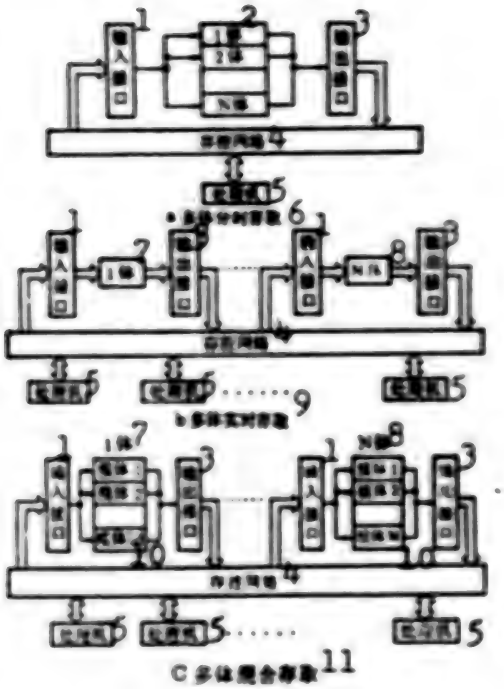

Fig. 1. Organization of multiple storage.

Key:

1. Input interface
2. Storage 1, storage 2..... storage N
3. Output interface
4. Storage and control network
5. Processor
6. Multiple storage time-shared access
7. Storage 1
8. Storage N
9. Multiple storage real-time access
10. Module 1, module 2 ..... module M
11. Multiple storage hybrid access

The method of storage organization should be chosen based on the overall requirement of the computer system. We opted for the multiple storage hybrid access mode with a main storage capacity of 2048K x 40 bit (including 8 Hamming correction bits), divided into 16 storage units (plus 2 spares) controlled by 2 storage and control networks. Each storage is further divided into 4 modules with 32K words, each operating in a time-shared mode. The main storage cycle is 400 ns; therefore, the maximum signal transmission rate of the main storage is $64/400 \times 10^{-9}$ = 160 mega words/second.

2. Choosing a Storage Device

The primary consideration in choosing a storage device is rational selection of the type of device and its performance specifications. In general, there are three types of storage devices (refering to RAM) in computer systems: low-capacity high-speed buffer storage; large-capacity main storage; and exclusive storage for external facility, channel, and terminals. The design of the computer system specifies the capacity and speed requirements of the high-speed buffer storage and the main storage; their speed ratio is usually 1:5$\sim$10 and their capacity ratio is at least 1:10. It is therefore appropriate to use high-speed bipolar RAM for high-speed buffer and large-capacity dynamic MOS RAM for main storage. Special component storages should be chosen according to the needs, and preference should be given to static MOS RAM because of their low power consumption; refresh control can be avoided. In our design we chose 1K ECL bipolar RAM to provide 16K x 40 bit high-speed buffer storage and 16K dynamic MOS RAM to provide our main storage of 2048K x 40 bit total capacity. Because static MOS was not available, we used 4K dynamic MOS RAM to provide 4K x 8 bit storage for the display device and simplified the refresh control by having refresh implicitly contained in the duty cycle. The second consideration is universality and expandability of the lead-out wires and different supply source. At present, 4K, 16K and 64K dynamic MOS RAM in foreign countries all have compatible leads, and components can be readily interchanged to expand the capacity by four times. The third question is an economic one, that is, the optimum performance-price ratio. Whether to adopt devices of a higher degree of integration can only be decided after an overall evaluation of the cost per bit and the cost of testing and assembly. The fourth consideration is stability and reliability of device production. It is best to select products that have undergone 1 or 2 years of production and are being supplied to users in volume. Test procedures and reliability test data should be obtained from the manufacturer whenever possible.

3. Designing the Peripheral Circuitry

1) Choosing the Type of Peripheral Logic Circuitry

Except for ECL bipolar RAM, the input and output voltages of most RAM devices are TTL voltage. Hence, TTL components should be chosen for the peripheral logic circuit of the storage system to avoid the voltage conversion problem. But sometimes ECL logic circuits are also used to reduce the time for address decoding, clock transmission and data correction in cases where the system requires rapid number retrieval from storage. For example, in the design of the main storage, considering that the system requires the storage to output a number in less than 240 ns (including Hamming check), which is not possible with TTL logic, and considering that the mainframe already uses ECL logic components, we opted for the MECL 10K series devices. In the storage for the 4K x 8 bit display, we used a TTL peripheral logic circuit which has the same voltage as the interface to external devices.

2) Choosing a Driver

Since the chip selector and address line of all the RAMs in the storage matrix are connected in parallel, it puts a large load demand on the front stage driver. For MOS RAM devices, the input terminal has a high impedance and the input current is in the microampere range; hence the load requirement for the front stage driver is primarily the ability to drive a large capacity load. We used a MC10177E-NMOS as the driver which has a maximum capacity load of 350PF. Considering stray capacitance of the circuit and maintaining a safety factor, the design allows each driver to drive no more than 16 MOS RAMs. The storage matrix of the display has only 8 MOS RAMs, so the two input terminals and the passive gate (DEG14C) of TTL will suffice.

3) Designing the Timing Sequence Circuit

The time sequence circuitry has an important effect on the reliability of the storage system. Accurate and versatile timing is an important criterion for high-speed operation of the storage system and maximum supply capacity. There are different methods for designing the time sequence circuit; Table 1 lists the five principle methods.

In view of the simple time sequence and the short delay time of the ECL bipolar RAM, we used a delay line for the time sequence circuit in our design of the high-speed buffer storage. In the MOS storage exclusive to the display, although the time sequence is relatively complex, due to the slower speed and the low demand on timing accuracy, a delay line is again used. For the large capacity MOS main storage, however, a shift register is used to produce the basic pulse sequence and a delay line is added for accurate timing, because here the time sequence is relatively complicated and there are certain requirements on the accuracy and versatility of the timing. Synchronization with the mainframe clock is achieved by triggering the clock oscillator externally with the mainframe access signal.

4) Refreshing Control of the Dynamic MOS RAM

Refreshing of the dynamic MOS RAM requires the execution of a refreshing cycle of all the addresses within a certain time interval (normally 2 ms in an ambient environment at +70°C).

The distribution method of the refreshing cycle can be: concentrated refreshing, distributed refreshing or fixed refreshing, as shown in Figure 2. In concentrated refreshing, the refreshing cycles of all the addresses are executed continuously within the refreshing period. Under the worst case, the mainframe would have to wait a time equal to the line number multiplied by the refreshing period. In distributed refreshing, a refreshing cycle is executed once every refreshing interval /line number, and the mainframe waiting time is shorter. The system elasped times are the same for the

Table 1. Practical methods for time sequence circuit

方 法[1]	最小脉宽[2]	最小定时改变量[3]	定时精确度[4]	定时改变灵活性[5]	评 价[6]
[7]单稳电路	>20ns	[8]连续可变	[9]对电源温度变化敏感	[10]灵 活	[11]线路简单，适用于脉宽较大，定时精确度要求不高的场合。
[12]延迟线	[13]取决于信号波形及延迟线抽头	[14]取决于延迟线抽头	[15]电源变化影响传输信号波形	[16]改变延迟线抽头或调节延迟线长度	[17]延迟线要仔细匹配，波形整形，适用于时序较简单的场合。
[18]计数器加译码器	[19]取决于时钟频率	[20]取决于时钟频率	[21]取决于时钟频率稳定度	[22]改变译码器引出头	[23]电路较复杂，采用器件较多，要和主机时钟同步，适于时序较复杂而变动较少的场合。
[24]移位寄存器	[25]同 上	[26]同 上	[27]同 上	[28]改变寄存器输出头	[29]同 上
[30]可 擦 PROM	[31]取决于 PROM 编程数时间及时钟频率	[32]同 左	[33]同 上	[34]改变 PROM 内容	[35]电路复杂，采用器件较多，要和主机时钟同步，适于时序要求复杂且灵活改动的场合。

Key:

1. Method
2. Minimum pulse width
3. Minimum timing change
4. Accuracy
5. Versatility
6. Evaluation
7. Monostable circuit
8. Continuous variable
9. Sensitive to temperature change of the power supply
10. Versatile
11. Circuit is simple. Suitable for cases where pulse width is large and timing accuracy requirement is not high
12. Delay line
13. Depends on signal waveform and delay line tap
14. Depends on delay line tap
15. Changes in power supply affect transmitted waveform
16. Alter delay line tap or adjust delay line length
17. Delay line must be carefully matched and waveform carefully shaped. Suitable for simple timing sequence

[Key continued on following page]

[Key continued]

18. Counter plus decoder
19. Depends on clock frequency
20. Depends on clock frequency
21. Depends on the stability of the clock frequency
22. Alter decoder lead-out
23. Circuitry is relatively complex and uses more components; must be synchronous with mainframe. Suitable for cases where timing sequence is relatively complex but does not have many changes
24. Shift register
25. 26. 27. Same as above
28. Alter shift register output lead
29. Same as above
30. Controllable PROM
31. Depends on the worst case of the PROM access time and the clock frequency
32. Same as the left
33. Same as above
34. Change the content of PROM
35. Circuit is complex and has many components, must be synchronous with mainframe. Suitable for cases where the timing sequence is complicated and versatile changes are required

above two methods. In fixed refreshing, the refreshing cycle is contained implicitly in the duty cycle of the storage and in this method the duty cycle period of the storage is the sum of the read/write period and the refreshing period. The choice between the three methods should be made based on the allowable waiting time of the mainframe in random accessing the storage and requirement of the duty cycle of the storage.

There are three modes of operation regarding the access request and refresh request of the processor: asynchronous refreshing, synchronous refreshing and senisynchronous refreshing (see Figure 3). In asynchronous refreshing, access request of the processor and refresh request of the storage are judged by the refresh control as two independent "events" on the basis of "first come, first serve." It requires the processor to wait when the storage is busy refreshing. In order to resolve the competition between access and refresh, the design of the refresh control would have to be more sophisticated, and the time for the storage to output a number would therefore be prolonged. The advantage is that the storage system has more independence. In synchronous refreshing, the refreshing cycle is executed when the processor is not accessing the storage. It requires the processor to have a definitive "not accessing" period and its refresh control is simpler. The fixed refreshing method described above is one form of synchronous refreshing. Semisynchronous refreshing works the same way as synchronous refreshing except that the refreshing timer is synchronized by the main clock provided by the processor. In general, the access request

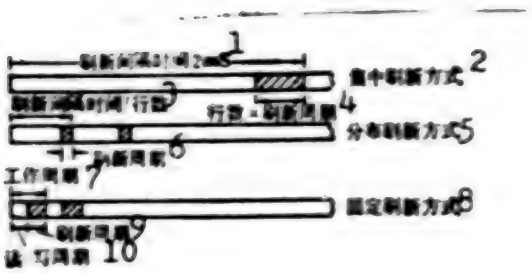

Fig. 2. Refreshing cycle distribution of dynamic MOS RAM system.

Key:

1. Refreshing interval 2 ms
2. Concentrated refreshing
3. Refreshing time interval/line number
4. Line number x refreshing cycle period
5. Distributed refreshing
6. Refreshing period
7. Duty cycle
8. Fixed refreshing
9. Refreshing cycle period
10. Read/write cycle

is generated during the ascending edge of the main clock, and the descending edge of the main clock is used to synchronize the refreshing timer, thereby avoiding the "competition" problem and, also, the output time of the storage is not prolonged by the refresh control. In our MOS main storage design we used semisynchronous distributed refreshing and in the display storage we used synchronous fixed refreshing.

4. Designing the Self-Checking Circuit

In order to carry out effective checks and tests of the storage system, self-checking circuits must be designed. This should include time sequence and control, address generator, data pattern generator, readout comparator, error recorder and display panel. Because of the intrinsic sensitivity to pattern of semiconductor storage devices, the self-checking circuit is rather complex. There are three self-checking circuit designs:

1) Hardwired Assembly Logic

Based on the necessary data pattern and regularities of address change, a control flow chart is first made. It is then reduced to a truth table and simplified into control logic equations by Boolean algebra, and finally engineering designs are made. Assembly logic suffers very little transmission delay, and the self-checking circuit based on it can produce high-speed changes in the address and data pattern. However, the logic design

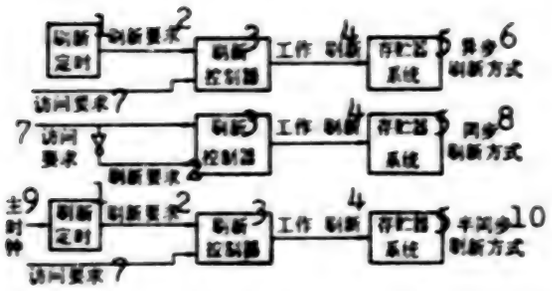

Fig. 3. Refreshing synchronization operation of dynamic MOS RAM system

Key:

1. Refreshing timer
2. Refresh request
3. Refresh control
4. Busy/refresh
5. Storage system
6. Asynchronous refreshing
7. Access request
8. Synchronous refreshing
9. Main clock
10. Semisynchronous refreshing

of this type of self-checking circuit is complicated, requires more components, and once it is finalized the testing pattern is fixed and lacks versatility. It is suitable for testing high-speed bipolar storage systems where the testing pattern is already fixed.

2) Microprogram Controlled Self-Checking Circuit

Using a microprogram address counter, microcommand storage addresses are produced. The microcommands are read out and address change, data pattern and R/W control of the storage system being tested are generated. Microprogram transfer address and control microprogram address count are also produced based on the signal according to the corresponding digit of the microcommand. The advantages are versatile test pattern (by changing the content of the PROM), simple logic design, fewer components and convenience of use and maintenance. However, its operating frequency is affected by the PROM readout time and the transmission time in the microprogram counter.

3) Microprocessor Controlled Self-Checking Circuit

The basic method is the same as the microprogram controlled self-checking circuit; the difference is that its address generator, data pattern generator and pattern comparator are all operated with microprocessors. Its advantages

are more versatile pattern testing and address changing for more convenient multidigit data pattern comparison, fewer components and simple hardware logic design. However, the operating speed is limited by the speed of the microprocessor, word length of the microcommand storage is longer, the design of microprogram is more complex, and design and maintenance personnel must be familiar with the use of microprocessors.

Each of the three schemes described above has its own advantages, disadvantages and adaptability, but they all require a certain amount of hardware. From the system economy viewpoint, they are used only in large-capacity multiple storage systems so that self-check and maintenance can be carried out for various storage units whenever desired. In our design, a microprocessor controlled self-checking circuit is installed for every eight storages in the MOS main memory; for high-speed buffer storage, no on-line self-checking circuits are included.

5. Division of Plug-in Circuit Board

Plug-in storage is an important part of semiconductor storage systems and it requires a matrix layout. The division of plug-in depends primarily on the structure of the storage matrix and secondarily on the consideration of less connection lines between plug-ins and clear logic division. We included the following considerations in our design:

1) The basic storage matrix is 4 x 8 and the plug-in dimensions are determined on this basis.

2) Except for the storage matrix and the necessary driving circuit and output interface circuit, no other logic circuits are installed on the plug-in storage board. The plug-in storage is modularized for more convenient combination and expansion of the capacity and word length.

3) We have carefully compared and optimized the number of modules, capacity and word length of a given plug-in storage. Table 2 lists the various plans of a MOS main storage plug-in. We opted for the 2 x 32K x 8 bit structure because it uses fewer components, has the minimum number of lead-out lines, and the 8 bit character length is convenient for parity check and malfunction diagnosis according to bytes.

Measures To Improve the Reliability of Semiconductor Storage System

The reliability of the semiconductor storage system is the combined result of a number of factors, including reliability of the semiconductor storage device and the peripheral logic circuitry, rigorousness of component testing and screening, wiring layout of the plug-in board and chassis, quality control of the production, calibration technique and the fault tolerance of the system design. Some of the problems are beyond the ability of the storage worker. In the space below we shall describe only the measures taken in storage system design.

Table 2

模体数×容量×字长 1	存储器件数 2	驱动器件数 3	插件板功耗 4	输出口数 5	信号引出线数 6
4×32K×4位 7	32	16	24.4瓦 8	1	100
2×32K×8位 7	32	10	18.5瓦 8	2	68
1×32K×16位 7	32	8	18.1瓦 8	4	70

Key:

1. Module number x capacity x word length
2. Number of storages
3. Number of drivers
4. Power consumption of plug-in
5. Number of output interfaces
6. Number of signal leads
7. Bit
8. Watt

1. Rigorous Testing and Screening and Systematic Checking

Rigorous testing and screening and systematic checking are crucial steps in insuring the reliability of storage systems. Not only D.C. characteristics and performance and dynamic characteristics should be tested, but separate tests should be made on the three stages of component, plug-in board and system. In the meantime, effects of ambient temperature and power source drift should also be taken into account. Figure 4 is a flow chart of the testing.

1) Inspect all components upon arrival and conduct aging tests. Using a static parameter testing station, test all D.C. parameters. Perform six pattern tests ("1" and "0" scan, walk, jump, jump and recovery, neighbor interference and calibration board) at a function testing station. A power supply pulling test should be carried out for both the above tests. The test on arrival can be carried out at room temperature only for speedy testing.

2) Storage boards are tested with a homemade semiconductor function tester. The tester has a maximum operating frequency of 20 MHz and can provide various test patterns; it has a programmable power source, and a clock can be conveniently set on the panel. Tests are conducted at the actual operating frequency of the storage, and $V_{DD}= f(V_{BB})$ operating range is found with the worst case pattern at 70°C. In addition, spot checks of high-speed dynamic characteristics testing by varying the phase clocks are conducted for the storage boards. This test not only checks all the components on the board and measures the operating range, but it also tests whether the wiring layout on the board is sensible.

3) The purpose of testing the storage system is to test the overall function of the system, to measure the operating range of the system for various patterns and to examine the reliability of the system.

4) After the storage is in on-line operation, it is again checked with the function testing program, and errors are recorded with software.

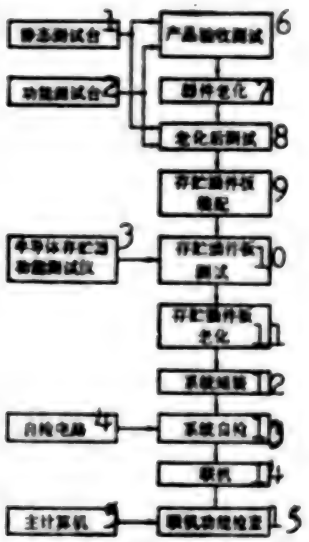

Fig. 4. Flow chart for testing semiconductor storage system.

Key:

1. Static testing station
2. Performance testing station
3. Equipment for testing the function of semiconductor storage
4. Self-checking circuit
5. Main computer
6. Product testing upon arrival
7. Component aging
8. Testing after aging
9. Assembly of storage plug-in board
10. Testing assembled storage board
11. Aging of storage plug-in
12. Assembly of system
13. Self-checking of system
14. On-line connection
15. On-line performance check

2. Rigorous Design of Storage Board Layout

The key to the engineering design of the semiconductor storage is a rational layout of the board. In contrast to a logic device, a storage device has many signal input leads that act simultaneously and coherently. When a large number of storage devices are put together to form a storage matrix, these leads are connected in parallel. Concurrent switching of signals on these parallel leads requires a high peak current from the supply and induces a large induction voltage on the leads to the supply. Furthermore, the parallel

input leads also produce a large induction voltage and oscillating waveform at the front stage driver. These effects are even more serious in large-storage matrices and high-speed storages. If these problems are not solved, they will not only place a higher demand on the dynamic load characteristics of the supply and the driver, but will also generate serious noise interference within the board. In order to solve these problems, the following measures should be taken:

1) Install distributed decoupling capacitors. The power supply system of a storage matrix is actually an inductance-resistance network (see Figure 5). L_1R_1 and L_2R_2 are respectively the equivalent inductance and resistance of the power supply main line and power leads between the RAM's. A high-frequency decoupling capacitor C_2 is installed at every supply connection of the RAM to provide most of the peak current during signal switching so that transient current fluctuation and induction voltage of the power supply can be reduced. C_1 is used for low-frequency decoupling for the entire storage matrix.

2) Use a multilayered printed circuit board. An effective method for reducing lead induction is to design a network of power supply and ground wire. Supply leads and wires should be wide so as to reduce resistive voltage drop. For dynamic MOS RAM, the order of line width should be ground, V_{DD}, V_{BB} and V_{CC}.

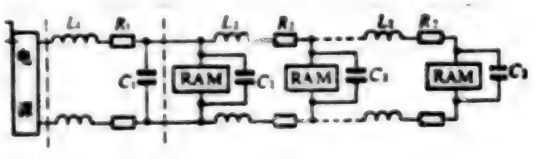

Fig. 5. Equivalent circuit of a storage matrix.

Key:
1. Power supply

3) Install damping resistor at the output terminal of the driver to smooth out the induction voltage and waveform oscillation produced by signal switching.

4) Since bipolar storages require large and stable D.C. current, they should have even wider supply and ground leads. All bipolar storages have a single power supply; this requirement is easy to satisfy.

In our layout of the MOS main storage board, we used six-layered printed board--four layers of signal leads and the other two layers, respectively, for horizontal and vertical power supply and ground leads. The dimension of the printed board is 280 x 180 mm^2. It has a 72 line plug, with 40 leads for power supply and ground, and the remainder are signal leads. A V_{DD} = +12V and V_{BB} = 5V. A 0.33 μF high-frequency decoupling capacitor is

installed for every two RAM's. At the power supply input terminal, a number of 22 μF capacitors are connected in parallel for low-frequency decoupling; V_{DD} has 16, V_{BB} has 12 and V_{CC} has 5.

3. Sensible Use of Correction and Diagnostic Techniques

For output, the Hamming code is used to correct a single error and sort out a double error. A parity check is performed on the input address and input data, and a checking circuit is installed for the control signal. After the storage is in operation on-line, the operating system software is used to record errors of the storage. This is very useful for understanding the reliable operation of the storage system and for diagnosis and maintenance.

For high-speed buffer, since the Hamming code occupies peripheral time of the storage and affects the readout speed, a choice must be made after weighing the plus and minus of speed and reliability.

4. Installation of Redundant Units

In cases where high reliability is demanded, redundant units can be installed. When an error appears in a certain storage and cannot be corrected, the operating system can automatically switch a redundant unit into operation and the malfunctioning unit is then self-checked, fixed and used as a spare.

Suggestions on the Modularization and Standardization of Semiconductor Storage Systems

Semiconductor storages are easy to modularize and standardize. In China, an early solution to this problem before semiconductor storages are extensively in use in computers will aid the rapid development of semiconductor storage systems.

1. Serialization of Storage Devices

In the development of semiconductor storages in China, we should draw on foreign experience; conduct extensive surveys on the application situation of semiconductor storage devices in China, the customer needs, and the level and characteristics of Chinese semiconductor storage technology; and produce quality products (including circuit structure, characteristics parameter, lead arrangement, external dimension and testing codes) to gradually form a series for the user's choice.

2. Modularization of Storage Matrix

Concerning the question of arranging storage matrices on a board, we recommend 4 x 8 or 4 x 9 storage devices as the basic storage matrix module. They are favorable for word expansion, adaptable to the load of driver, and the board dimension is also suitable.

3. Standardization of Board Dimension

We recommend the establishment of several standard board dimensions and structural formats based on the basic storage matrix module, including the number of layers of the printed board, arrangement of the power supply lead-in wires, the number of lead-out wires and external profile and dimension, coupled with the corresponding standard plugs (single and double plugs). This is not only favorable to the modularization and standardization of storage devices but also conducive to the gradual unification and compatibility of computers.

4. Simplification of Self-Checking Circuits

In large-capacity multiple storage systems, it is necessary to install a self-checking circuit that is complete, versatile and has sophisticated logic. For mass-produced medium- and small-capacity modularized storage, however, a complicated self-checking circuit will increase the cost and the difficulty of service and is not favorable to the modularization and standardization of the storage device. An alternative is to conduct all function testing with comprehensive semiconductor storage testing equipment when the storage modules come off the machine, and provide only a simple self-checking circuit inside the storage system.

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FREQUENCY SYNTHESIZER APPLIED TO LASER TECHNOLOGY

Beijing DIANZI KEXUE JISHU [ELECTRONIC SCIENCE AND TECHNOLOGY] in Chinese No 1, 19?? pp 33, 11

[Article by Zhong Deyuan [6945 1795 0337], Wu Longbiao [0702 7893 2871] and Yu Guanhe [0151 0385 0735] of the China University of Science and Technology: "Laser Application of Frequency Synthesizer"]

[Text] The frequency synthesizer described in this paper has been successfully used to mode-lock two lasers. From this practice we have realized the following: 1) The variable frequency signal source allows a lower dimension tolerance of the modulator, reduces machining time and cost, and improves the acceptance rate of the product. In the meantime, there is no need to change the signal source when the modulator is changed. 2) It facilitates the investigation and measurement of modulator parameters such as the optimum frequency and power rating of the modulator. This provides a method for designing a high-performance modulator and operating the modulator in its optimum condition. 3) It makes the tuning of a laser modulator more convenient and operation more stable. In the initial tuning or in the retuning after temperature change, mode locking can be readily achieved by adjusting the modulation frequency and the cavity length. Since the modulation frequency is highly stable, the operation is also stable. We therefore believe the frequency synthesizer is an important component of the actively mode-locked laser, and other signal sources cannot compare.

1. Requirements

Center frequency: 50 MHz, tunable range 50 ± 1 MHz, frequency jump step 1 KHz, output power is tunable with a maximum value of 3 watts, frequency stability better than 10^{-7}/sec.

2. Method

Based on the above requirements, we designed the synthesizer shown in Figure 1. The 5 MHz output signal from the high-stability crystal oscillator is divided by 50 and 500 and then given respectively 100 KHz and 10 KHz square waves and these become the reference signal for the $49 \sim 50.999$ MHz phase locked loop

and the 1.00～1.99 MHz phase locked loop. The 1.00～1.99 MHz VCO uses an integration monostable circuit in producing 1.00～1.99 MHz square waves, which are then added to the variable frequency divider and the decade frequency divider. The frequency division ratio of the variable frequency divider is in the range of 100～199 so the frequency after division is 10 KHz and the frequency step is also 10 KHz. This 10 KHz square wave signal and the 10 KHz reference signal are discriminated in a current type phase discriminator, the error signal after the discriminator is returned to control the frequency of the VCO and forms a phase locked loop. The other output signal of the VCO is divided by a decade frequency divider and added to the current type phase discriminator of the 45.100～45.199 MHz phase locked loop. The other signal to the discriminator is a 45 MHz sine wave signal produced by a 5 MHz signal going through a 9 x frequency doubler. This sine signal is mixed with a 45.100～45.199 MHz signal, coming from the output of an LC push-pull negative resistance voltage controlled oscillator, in a balanced mixer to get the difference frequency. After filtering, amplification and shaping, the output is a 100-199 KHz square wave signal. The two equal frequency 100～199 KHz signals are discriminated in a discriminator and the error signal is returned to control the VCO and forms the second phase locked loop. Since the output signal of the phase locked loop is fed through a decade frequency divider and used as the reference signal for the second phase locked loop, therefore the frequency of the output signal from the second phase locked loop is 45.000～45.199 MHz with a frequency interval of 1 KHz and a variation range of 100 KHz. This signal is added to the balanced mixer of the third phase locked loop with the 49.000～50.999 MHz signal from the VCO; the difference frequency is filtered, amplified and shaped to form a 3.9-5.8 MHz square wave and fed into a 39～58 times variable frequency divider. The output from the variable

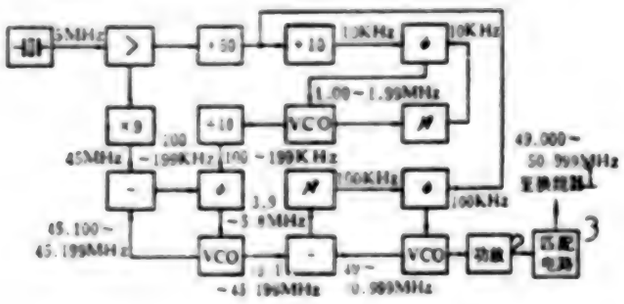

Fig. 1.

Key:

1. To transducer
2. Power amplifier
3. Matching circuit

frequency divider is a fixed 100 KHz square wave; it is processed in a current type phase discriminator with a 100 KHz reference signal. The error signal from the discriminator is used to control the LC push-pull negative resistance voltage controlled oscillator in forming the third phase locked loop. The other output of the VCO goes through a variable attenuator and a power amplifier and is fed into an impedance matching circuit so that there is sufficient power to drive the transducer in the electricity-sound conversion.

9698
CSO: 4008/72

MINERAL PROCESSING PROGRESS OF METALLIC ORES

Beijing YOUSE JINSHU [NONFERROUS METALS] in English No 1, 1982 pp 36-37

[Article by Shi Daxin [4258 1129 2450] (Senior Engineer of Beijing Mining and Metallurgical Research Institute)]

[Summary] China is known for its richness in metallic ore resources with almost all varieties, having a long history of mining activities. Throughput has been constantly increasing, while technology improving.

Despite of the raw ore grade decreasing, recoveries of main metals have been raising and kinds as well as the output of by-products expanding. The present paper describes the progress in grinding, classification and in the beneficiation of tungsten, tin, complex sulphides, copper, molybdenum, nickel, precious metals and iron ores.

GRINDING AND CLASSIFICATION Autogenous and semi-autogenous mills have been increasingly used, especially in iron concentrators. In some plants, magnetic pulleies are used to discard wastes from autogenous mill discharges. Comparing with ball mills, the consumption of grinding media has been reduced by 40% in plant using rod-pebble mills. The fine screening with rappers has been widely adopted in magnetite plants for upgrading concentrates. In some plants, hydrocyclones have been replaced by F. S. R. unites as classifiers.

TUNGSTEN AND TIN Although multistage grinding and gravity separation are mainly applied to the beneficiation of such ores, combined flowsheets of gravity, magnetic separstion and flotation are also used. In the treatment of ore slimes, gravity method with centifugal separators for roughing followed by vanners for cleaning is successfully adopted; flotation and combined processes of gravity separation and flotation have been increasingly used; rock-shaking vanners are also introduced. Progress, in the concentration of tungsten ore slimes, has been made by way of high intensity magnetic separation followed by flotation. The methods of cleaning rougher concentrates comprise gravity, magnetic, electrostatic separation, table flotation and flotation as well as combined processes of beneficiation and metallurgy. Some concentrators treating refractory cassiterite ores produce, in addition to final tin concentrates, low grade semi-products for further treatment with special metallurgical processes.

COMPLEX SULPHIDES In respect of the methods of separation, many a cyanide-free and dichromate-free separation methods have been developed, resulting in improvements of separation efficiency; reduction of environmental pollution and increasing recovery of precious metals; and solution of the problems associated with separation

of some complex sulphide ores, containing a large amount of secondary copper minerals. In addition, the electroflotation technique has been introduced in a lead-zinc concentrator, resulting in saving regulators and depressors. As concerns the flotation flowsheet, "equi-flotability" has been widely used.

COPPER A number of effective flotation reagents have been utilized. Flotation columns have been used for more than 20 years, and a new type annular-ejecting flotation machine has also been put into operation. With respect to the recovery of refractory oxidized ores, both the single stage segregation with direct heating and the leaching-extraction-electrowinning processes are in operation. Some other methods have also been investigated with better results, such as, pressure ammoniacal leaching, pressure ammoniacal leaching with sulphur precipitation-flotation, pressure sulphidization-flotation and leaching-precipitation-carrier flotation.

MOLYBDENUM, NICKEL AND PRECIOUS METALS The flotation flowsheet of molybdenite trends towards open circuit, i. e. discarding final tailings in cleaning stages. Furthermore, some concentrators also produce middlings for further treatment with hydrometallurgy. Heavier wax and combined collectors are adopted in some concentrators, improving molybdenum recoveries.

In a certain plant dealing with difficult nickel ores, flotation-desliming-magnetic separation-flotation flowsheet has been used instead of single flotation. Recovering cobalt alloy from converter slags and separating richer precious metal alloy from nickel matt with ore dressing methods have been put into practice.

Extracting gold with thiourea has been investigated in commercial scale test with better results achieved. Recovering precious metals from anode slime and leaching residues by means of flotation has also been carried into effect.

IRON In order to better metallurgical performances of some hematite ores, a number of promising means have been found out. The magnetic separation-gravity separation process (spiral chutes for coarser fraction, and centrifugal separators for finer one) has been gone on stream. The magnetic separation-high intensity magnetic separation -weakly acid flotation has also been in operation. For treating fine grain iron ores, the selective flocculation-desliming process employing ammonium humic acid as a flocculant has been tested commercially with satisfying result. Another experiment using the same process and sodium silicate to promote selective flocculation for a complex iron ore has also been conducted successfully in pilot scale test.

In order to recovering ilmenite from tailings of a magnetic concentrator, a plant adopting gravity-high tension separation process (Humphrey spirals for coarser fraction and spiral chutes for finer one) has been set up. Through trial production the concentrate assaying 46–48% TiO_2 has been produced.

CSO: 4010/2

OPERATION, PRODUCTS OF SHANGHAI SMELTER DESCRIBED

Beijing YOUSE JINSHU [NONFERROUS METALS] in English No 1, 1982 pp 82-84

[Article by Liu Yaozhong [0491 5069 0022]

[Text] **Liu Yaozhong**, *a deputy chief engineer, is a fellow of the Academic Committee of Heavy Metal Metallurgy, attached to the Chinese Society of Metals and a member of the Council of Shanghai Metal Association.*

After graduation from Zhejiang University in 1950, he successively held posts of the director of the central lab and the deputy chief engineer of the Shanghai Smelter. With great diligence and conscientiosness, Liu Yaozhong has been working in the fields of heavy metal metallurgy and germanium and silicon as semiconductor materials for over thirty years. He has made some contributions to the Smelter in the development of its production, the improvement of its technological process as well as the management of the Smelter.

Shanghai Smelter, located in the City of Shanghai—the largest industrial base which has lots of transport facilities and railways leading to all parts of our country, is one of the non-ferrous metallurgical plants of the People's Republic of China. The Shanghai Seaport is also well-known in the world, which can berth in the harbour ocean-going ships from different countries.

Shanghai Smelter is an old plant. Before 1949, on a small scale, it could only produce single product of 410-ton electrolytic copper, using cupric coin as raw materials. And it had only 197 employees altogether.

Since the founding of the People's Republic of China in 1949, the Smelter has made rapid strides as a result of the performance of our National Economy Programme. For example, last year it produced 65,000 tons of electrolytic copper, 70,000 tons of wire bar and other 50 varieties of products. Now the Smelter has 10 sections, which are scattered in several districts of this city.

The Smelter has a capacity of producing base, precious and rare metals, chemical compounds, semiconductor material, brass strips, electrolytic copper foil, metals of high purity. The quality of most products has reached an advanced level, as compared with the same ones in the world.

The Smelter is supplied with the blister copper as raw material partly from Anhui and Hubei Provinces of our country, partly imported from Peru, Zambia and Chile. And

there are large quantities of waste materials being used, such as, scraps of copper, lead, nickel alloy, cobalt alloy, germanium as well as precious metals-containing scraps. As potential power of processing those scraps is available in our Smelter, we hope that we could get those scrap materials from abroad.

Now, the Smelter is able to produce six varieties of products which are as follows:

1. **Heavy metals**——copper, wire bar, nickel, cobalt, lead, bismuth and Babit alloy.

2. **Precious metals, rare metals, high purity metals and compounds**——gold, silver, platinum, palladium. Some metals are of 99.99% purity, those are tin, lead, indium, selenium aud tellurium.

3. **Semiconductor materials**——germanium ingot, zone-melting germanium ingot, germanium single crystal and wafer, monocrystalline silicon, zinc selenide and lead telluride.

4. **Compouds**——copper sulfate, nickel sulfate, cobalt sulfate, cobalt acetate, stannous chloride, sodium stannate, litharge (lead monoxide), germanium tetrachloride, zinc sulfate and zinc oxide.

5. **Strip and foil**——brass strip and eletrolytic copper foil.

6. **Other products**——selenium drum for duplicator, semiconductor refrigerator alloy, composite powder for spray plating on metallic surface.

In the Smelter, there are some small-sized mechanical devices which are designed and installed by itself. For example, the bridge-type charging machine for reverberatory furnace, startig sheet machine, anode ear-correcting and arranging machine, electrolytic copper washing and arranging machine. The labour intensiy is greatly lowered owing to these machines.

Certain amount of elements added in anode promotes the precipitation of anode slime. By mixing up complex additives into the electrolyte and by other efficient means, the current density of cathode reaches $330A/M^2$. The distance between the same electrods is 75mm, and the utilized coefficient of cell remains $146Kg/M^3$ a day. This figure is about 150% of that of the same kind of plants in the world. The purity of copper reaches 99.98%, bearing 8ppm of silver. Having controlled the oxygen and sulfur, the conductivity of wire bar with the cathode as raw material remains approximately 101.0—101.5%, which approaches the standards of the same kinds abroad. And wire bar may also be drawn into the finest wire up to 0.015 or 0.02mm in diameter. Electrolytic nickel of 99.99% purity and nickel sulphate are extracted from scraps of kel alloy, which is one of the characteristics of the Smelter. Another feature is: by using the scrap and sweep of transistor plants, it produces germanium ingot, zone-refining ingot, single crystal and wafer by means of chemical extraction and purification, zone-melting, and vertical pulling (Czechraliki Technique), cuttiug, grinding and polishing. This kind of wafer with definite parameters can be directly used in making diodes, transistors etc. It is estimated that the Smelter will produce 7000Kg of monocrystalline germanium and 13000Kg of wafer in 1981. Also, an increase can be expected in the next year.

The properties of pin hole, resistivity, tensile strength, and stability of colours of electrolytic copper foil in rolls are close to those of the same products abroad. The thickness of foils is about 35 μ and 50μ or according to the customers, the maximum width of which is some 1060mm. The water used in making of copper foil is purified by electrolytic dialysis.

The comprehensive processing of the "three wastes", (waste residue, waste water and waste gas) is the main task in production. The large amount of the wastes has been recovered and turned into chemical compounds. That is benificial to both the Smelter and customers.

Eighteen years have passed since crystalline nickel sulfate was separated out of copper electrolyte and purified. Recently, the Smelter began its production of sodium stannate from flue dust. From scrap lead, by means of wet method, the production of litharge has begun, which is a raw material for high refractive optical glass. The impurities with colours, such as copper, iron, nickel, cobalt, chromium, manganese and vanadium are very small: 0.1 to 2ppm or less. Germanium tetrachloride used for optical-fiber is highly purified to 8N.

The anode slime from copper electrolysis is processed in a separate section to produce selenium, gold, silver, platinum and palladium. There were a lot of improvements in production facilities in recent years. The Smelter has designed and installed a rotary kiln, the sulfation and sublimation of selenium dioxide simultaneously took place in it. The charge and discharge of it went on continuously. Cupellation furnaces have become convertors instead of original fixed reverberatory furnaces. And the gas from the convertors is purified by pulse-bag filter. The collection of dust remains more than 99%.

The Smelter can produce selenium drums made of pure selenium and selenium alloy for duplicators bythe method of vacuum evaporation. Now drums of 240 and 129mm are being manufactured for duplicator factories.

In the Smelter, there is a special group which is making extensive study on several problems, such as reduction of energy consumption; research work on saving electricity, fuel oil, gas and coal. In this way the total amount of consumption of energy went down gradually year by year.

The Smelter also set up a central laboratory where there are many experienced engineers and technicians who are specially engaged in the study of technological process design of new products, environmental conservation and comprehensive utilization. The central laboratory has done a great deal in the development of the Shanghai Smelter.

CSO: 4010/1

PUBLICATIONS

TABLE OF CONTENTS OF 'HUAXUE TONGBAO' NO 9, 1981

Beijing HUAXUE TONGBAO [CHEMISTRY] in Chinese No 9, Sep 81

9717
CSO: 4008/39

AUTHOR: ZHENG Qilun [6774 0796 0243]
HUANG Guanguang [7806 6306 0342]

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TITLE: "A New Multiple-valued Logic Circuit: Application of Duoyuan Luoji (DYL) in the Development of Multiple-Valued Logic"

SOURCE: Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese No 6, Nov 81 pp 23-32

ABSTRACT: Although there have been advancements in the research of multiple-valued logic circuit (MV) since 1974, such as ternary CMOS and MV-I^2L, their realization involves engineering difficulties. This paper purports to point out that the linear AND-OR gate of Duoyuan Luoji, which is the Chinese Pinyin spelling of multiple element logic, DYL for short, created by Prof. WANG Shoujue [3769 1343 6030] of the Research Institute of Semiconductors Chinese Academy of Sciences [DIANZI XUEBAO No 2, 1978 pp 43-51 and No 1, 1980 pp 1-9] is in reality an excellent MV AND-OR gate. When it is combined with other circuits, a new type of MV, i.e. a MV-DYL circuit may be constructed. Advantages of MV-DYL are demonstrated by comparing it with ternary CMOS and MV-I^2L, as well as with binary DYL circuits. An analysis of the DYL circuit and the realization of basic computation in case of MV-DYL AND gate, MV-DYL OR gate, and MV-DYL THRESHOLD gate are introduced. The authors are preparing another paper on the logic design of MV-DYL, to be published in DIANZI XYEBAO soon. This paper was received for publication in Dec 1980.

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TITLE: "An Optimal Design Method of Constant-Delay Filter"

SOURCE: Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese No 6, Nov 81 pp 41-46

ABSTRACT: In order to meet the requirements of distortionless transmission of television, facsimile, and data signals, the need for designing a filter in accordance with the constant group-delay ripple tolerance occurs frequently in the engineering process. Although the method suggested by WANG Dejun [3769 1795 7165] in "Theory of Computer-aided Optimized Design of Linear Phase Filter" [BEIJING YOUDIAN XUEYUAN XUEBAO No 1, 1979] is usable, it is difficult to convert time delay ripple index to phase shift ripple index and many components are required. This paper introduces a method of starting from group delay directly, using high speed computer and the improved damping least square method to accomplish optimal approximation. Experimental design and test measurement proved the theory to be correct. The delay ripple is 30μs less and one fewer inductance component is needed, compared with the method proposed by WANG Dejun.
This paper was received for publication in Jun 1980.

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TITLE: "Computer-aided Design of Highpass and Lowpass Filters"

SOURCE: Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese No 6, Nov 81 pp 47-57

ABSTRACT: The use of the synthesis method to design filters was created by Cauer and Darlington in 1930. After the introduction of computers in the early 60's, the method was revived. If numerical place accuracy is to be maintained, a large computer must be used to execute the complex program computations in the various stages of synthesis, however. Taking into consideration the concrete condition in China, the paper proceeds to analyze the design theory of pass-band equiripple lowpass filters and point out that with some changes the technique of using transformed frequency variation (proposed by B.R.Smith in 1965 and R.W.Daniels in 1974) may also be used to design highpass filters. With this technique, long and complex numerical computation can be avoided, and the synthesis computation of a high grade filter may be accomplished in a small computer of 8-9 places of accuracy. With a program written by the authors (not given in the paper) 2 sample designs are provided. The paper explains in general terms filter design programs and a brief flow chart.
This paper was received for publication in Feb 1980.

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TITLE: "Design Techniques for Reliability of DG-1 Computer"

SOURCE: Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese No 6, Nov 81 pp 76-81

ABSTRACT: Following a general description of the DG-1 computer system, a small fixed point machine of a word size of 24 places used mainly in process control but also in scientific computation, this paper introduces the parity check technique which is installed in all important data channels of the DG-1. The fault probability and the reliability of the dynamic configuration of the central processing unit (CPU) are analyzed. The Hamming code is adopted to check the MOS memory. Several significant experiments have demonstrated the capability of the DG-1 to work reliably in controlling random emergencies. If various accessories are added and software measures are used to improve, continuously, the dynamic configuration, the reliability of DG-1 may still be guaranteed even under the condition of relatively poor maintenance and prolonged continuous operation.
This paper was received for publication in Dec 1980.

6248
CSO: 4009/222

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TITLE: "Vibration of Some Structures with Periodic Random Parameters"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 1-16

TEXT OF ENGLISH ABSTRACT: In a periodic structural system such as blades in a closed packet of turbomachinery, the natural frequencies of the individual blade can be randomly different from one another. This paper describes a solution approach to such a periodic structure in which the distributions of blade frequencies are random processes with small standard deviations. A spectral method is suggested to solve for differential equations with random coefficients. The expressions for vibration modes are given, the standard deviations of natural frequencies are estimated, and the results of forced vibration are presented. Some special features of vibration characteristics of this system are shown as well.

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TITLE: "The Tentative Model of Fracture Mechanism of Unidirectional Fiber-strengthened Composite under Tension"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 17-24

TEXT OF ENGLISH ABSTRACT: A volume element which consists of not only fiber but also the matrix around the fiber has been taken into consideration for the possibilities of tensile failure, shearing failure of matrix and interface failure. Three kinds of failure modes, i.e., basic failure, coupled failure and induced failure, are described by means of logic diagram. The corresponding expressions of reliability and failure possibility of the composite are given. Finally, the effects of length and cross section size of composite and volume ratio of fiber are discussed. The method to determine the critical stress and critical crack length is also presented.

The purpose of this paper is to get rid of the restriction of self-similar crack propagation assumption.

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TITLE: "New Method of Measuring Temperature Distributions with Orthogonal Metal Cutting"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 25-33

TEXT OF ENGLISH ABSTRACT: A new method of measuring temperature distributions in the cutting region is given in this paper. A thin wire of constantan (diameter 0.07 mm) is welded to the side of a workpiece as a thermocouple. With orthogonal cutting the tool passed beneath the wire, so that the wire passed up the tool face still welded to the chip. The tool passed over the wire and passed beneath the wire, and the wire-work thermocouple could possibly give the temperature field throughout the chip and the work. In this paper experimental method used by foreigners are evaluated, including the imbedded thermocouple method, the infrared photograph method, the infrared radiometric microscope method. Compared with all these methods, our new experimental method of measuring the cutting temperature field gives better results.

[Continuation of HARBIN GONGYE DAXUE XUEBAO No 2, 1981 pp 25-33]

The temperature field in the cutting region measured by our experiment gives interesting results: 1) the isotherms in the primary deformation zone are near the shear plane; 2) the maximum temperature in the chip takes place at the point where the chip leaves the face of the tool; 3) the maximum temperature in the workpiece takes place at the point where the cutting surface leaves the tool.

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TITLE: "Elements in the Beam-type of the Finite Element Method Used in the Calculation of Static and Dynamic Characteristics of Machine-tool Elements"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 34-42

TEXT OF ENGLISH ABSTRACT: In this paper, first of all we recount the defects of the calculating method which uses equivalent diameters and the advantages of the calculating method by the finite element method for elements of the beam-axle type. Then we introduce the ways of thinking and the outcomes of calculation of the program for the evaluation of static and dynamic characteristics of elements of the plat beam element. Then we give an example to illustrate the calculating peculiarities and the results of the large extension-arm with polygon-sections and slide block slipper of vertical boring and turing mills. In addition, in order to make

[Continuation of HARBIN GONGYE DAXUE XUEBAO No 2, 1981 pp 34-42]

a comparison with the evaluated results, we also list some measured outcomes in the practice of static deformation of the slide block slipper of vertical boring and turing mills.

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TITLE: "An Experimental Study of Superplastic Tin-Lead Alloy Thin-walled Tubes Subjected to Combined Stresses"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 43-54

TEXT OF ENGLISH ABSTRACT: An experimental study of superplastic tin-lead alloy thin-walled tubes subjected to axial tension compression with internal pressure is described. The main results of this study are as follows:

The actual yield stress values of the superplastic material observes the Mises yield criterion and approximately agrees with the Tresca yield criterion. Because the superplastic material is sensitive to strain rate, its yield locus, as shown in the article, expands out homogeneously with increasing strain rate. This result is given first. The results of this investigation show that the rule of correspondence between strain and stress order, given in a previous article, is correct.

[Continuation of HARBIN GONGYE DAXUE XUEBAO No 2, 1981 pp 43-54]

In addition, the results of this investigation show that the superplastic deformation stress-strain relation observes the flow theory under the conditions of changing stress order and corresponds to the total strain theory if the stresses do not deviate far from proportionality.

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TITLE: "A Study of Strengthening and Toughening Treatments of Ultrahigh-strength Steel 37SiMnCrNiMoV"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 55-69

TEXT OF ENGLISH ABSTRACT: In this paper, effects of various heat treating processes, including conventional quenching, quenching from high austenitizing temperatures, repeated quenching, austempering, etc., on strength and fracture properties of sheet steel 37SiMnCrNiMoV were studied. Experimental results show that high temperature quenching improves the fracture toughness of the steel, but leads to the reduction of impact toughness. The repeated quenching can offer an optimum combination of strength, fracture toughness and impact properties and, therefore, seems to be the best method for developing the property potential of the material.

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TITLE: "The Influence of Filter Cleaning on Fracture Toughness of an Aluminum Alloy"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 70-81

TEXT OF ENGLISH ABSTRACT: Based on the experimental results of plane strain fracture toughness and SEM fractography of the filtered and unfiltered LD_5 aluminum alloy specimens, the effect of non-metallic inclusions on the fracture toughness has been discussed. It has been shown that the fracture toughness of this aluminum alloy can notably be improved by filter cleaning and the value of K_{1C} can be increased by 12.7 percent under the conditions of these experiments. A close

[Continuation of HARBIN GONGYE DAXUE XUEBAO No 2, 1981 pp 70-81]

relationship between K_{1C} and $\bar{\lambda}$, the average distance of non-metallic inclusions in this aluminum alloy, has been established. The K_{1C} is in direct proportion to $\bar{\lambda}^{0.44}$ and this relationship has been demonstrated by regression analysis. The experimental results conform to theoretical deduction.

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ORG: Mathematics Teaching and Research Group

TITLE: "On the Existence and Estimation of the Mixed Generalized Partial Derivative in the Orlicz Space (I)"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 82-96

TEXT OF ENGLISH ABSTRACT: In this paper, we show that if function $\phi(x)$ satisfies: (1) $\phi(x) \in L_M^0(G)$ and the support of the function $\phi(x)$ strictly belongs to G, (2) for each variable $x_i (i = 1, \ldots, n)$, $\phi(x)$ has non-mixed generalized partial derivative $D_i^l \phi(x) \in L_M(G)$ and the support of $D_i^l \phi(x)$ strictly belongs to G, then the function $\phi(x)$ has all mixed generalized partial derivatives of order l in $L_M^0(G)$, and we also obtain the corresponding estimate. Where denoted by $L_M^0(G)$, the Orlicz space for N-function $M(u)$ on the domain G and l is a positive integer.

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TITLE: "Research of Etch Technique of Thin Quartz Oscillator"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 97-105

TEXT OF ENGLISH ABSTRACT: In this investigation, a chemical etch technique of fabricating thin quartz fork oscillators with thickness less than 0.1 mm and cut type x+5° is presented.

Using vapor chrome and gold to plate respectively on two sides of crystal ribbon polished to a mirror finish, outlines of forks and electrode lines can be etched on the two sides after applying a coat of glue. Tens to a hundred forks can be obtained on every crystal ribbon after laminated etching. Then mounting the forks and modulating the frequency, they can be used to enclose electronic watches as miniature oscillators.

[Continuation of HARBIN GONGYE DAXUE XUEBAO No 2, 1981 pp 97-105]

The main points of the above-mentioned processing have been described briefly in the paper. In addition, the characteristics and developments of the technique have also been pointed out here.

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TITLE: "Minimization of Fuzzy Logic Functions"

SOURCE: Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 2, 1981 pp 106-114

TEXT OF ENGLISH ABSTRACT: Some important concepts on fuzzy logic functions are presented simply, and a table method by which the fuzzy logic functions are minimized is provided in this paper. This method is different from those presented by Kandel, Rickman, Neff and Pepe. The essential and non-essential fuzzy prime implicants can by formed together by it. Thus, some theorems can be proved conveniently.

9717
CSO: 4009/270

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TITLE: "The Preliminary Practice of the Operating Control with Enlarged Charge and High Blast Temperature"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 1-4

TEXT OF ENGLISH ABSTRACT: The norms of the Chongqing Iron and Steel Company include two blast furnaces, each of 620 m^3. Due to the use of low grade iron ore with large quantities of slag, low sinter ratio, frequent change of charge and improper control of the upper and lower zones, both furnaces have a long period of lower gas utilization and less production efficiency.

In the last three years they have made good progress by improving the quality of materials, production management and the operation technique. The blast temperature has been increased from 850-900°C to 1000-1068°C. This has been achieved under the conditions of low grade raw materials and not using the injection of fuel.

It is pointed out in this paper that the most important thing in blast furnace operation is to choose the proper coke charge and use a fixed blast temperature with varying humidity as a control method. The ore charge has been increased to

[Continuation of GANGTIE No 1, 1982 pp 1-4]

18-20 tons gradually and the charging system has been changed from reverse filling (coke:ore) and semireverse filling (ore:coke:ore) into normal filling system (ore:coke). Thus the gas utilization has been increased 3-4 percent and the coke ratio has been greatly decreased.

AUTHOR: JING Dingzhong [5592 1353 0022]

ORG: Maanshan Iron and Steel Company

TITLE: "Experimental Study for Safe Injecting of Bituminous Coal into Blast Furnace"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 5-9

TEXT OF ENGLISH ABSTRACT: Injecting bituminous coal into the blast furnace is an important way of increasing the source of fuel for the blast furnace. Factors influencing spontaneous combustion and explosive properties of the bituminous coal have been studied in laboratories and safety measures in injection have also been suggested and put into practice. During the experiment operation, we analyzed the safety conditions of coal injection facilities, and measures for controlling the atmosphere, temperature and quick cutting of the coal supply under low pressure, etc., are taken. During the experiment, the operation of the furnace was quite stable and smooth and satisfactory results have been obtained.

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ORG: All of the Beijing University of Iron and Steel Technology

TITLE: "The Kinetics of Different Rare-earth Additives on the Oxidation Resistance of Fe-Cr-Al Alloys"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 10-18

TEXT OF ENGLISH ABSTRACT: Under the condition that the residual content of rare earth is fixed, the kinetic effects of different rare earth additives on the oxidation resistance of Fe-Cr-Al alloys at high temperatures have been studied. The apparent energy of activation in the range of 1250-1350°C is calculated. In addition, the mechanism of oxidation is discussed preliminarily.

The structure and composition of the oxide films were examined by metallograph, petrograph, X-ray, EPMA, IMP and SEM. The mechanism of the oxidation resistance of Fe-Cr-Al alloys with different rare-earth additives is discussed.

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CAO Hongwen [2580 3163 2429]

ORG: All of the Institute of Chemical Metallurgy, Chinese Academy of Sciences

TITLE: "Study of the Viscosity of Slag Containing Vanadium in Steelmaking"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 19-24

TEXT OF ENGLISH ABSTRACT: A study of the melting temperature, viscosity and mineral structure of the converter slag from Panzihua Iron and Steel Company and the synthetic slag indicates that V_2O_5 makes the melting temperature and the viscosity decrease obviously, and the vanadium in the slag with CaO forms calcium vanadate of a low melting point. It may be considered that V_2O_5 plays the role of diluent at the expense of the consumption of free CaO. That is why a large amount of CaO is needed during blowing to make a desulfurizing slag of high basicity. In basic slag, vanadium is found as a polyvaluent, with the 5-valuent prior to the 3-valuent vanadium in combining with CaO to form vanadate and the spinel of 3-valuent vanadium is also formed when the basicity decreases to 1.5 and the V_2O_5 increases to 20 percent.

AUTHOR: WANG Tingpu [3769 1694 3302]
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ORG: WANG Tingpu, LI and WANG Hangwen all of the Northeast Institute of Technology; HE of the Cold Rolling Plant, Aushan Iron and Steel Company

TITLE: "Study of Conditions of Rolling Stability and Forces Acting on the Rolls in the Unsymmetrical Rolling Process"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 25-31

TEXT OF ENGLISH ABSTRACT: In this paper through experimental study and theoretical analysis the following results are obtained:
1) With the reducing of the diameter of one roll by two-thirds, the folling pressure drops by 35-55 percent during rolling between rolls of unequal diameters (i.e., unsymmetrical rolling), greatly increasing the rolling efficiency.
2) The influence of various factors on the lateral force has been studied. The larger the angle of deviation of the smaller roll, the higher the rolling speed and the greater the amount of reduction and the greater the lateral force. The lateral force in the reverse direction rolling is much larger than that in positive direction rolling. In order to reduce the peak value of lateral force and to make it homogeneous, the diameter or speed of the upper driving roll should be properly reduced.

[Continuation of GANGTIE No 1, 1982 pp 25-31]

3) When rolled by single driving roll in unsymmetrical rolling, the result is reverse with double driving rolls. The lateral force in positive direction rolling is much larger than that in the reverse rolling. Therefore, the smaller roll should deviate toward the entrance of the pass (in reverse rolling).
4) The simplified formulas for calculating the lateral force and the optimum amount of deviation of the smaller roll are derived and essentially verified by experiments to a certain extent of deviation.

AUTHOR: SUN Benrong [1327 2609 2837]

ORG: Central Iron and Steel Research Institute

TITLE: "Recrystallization of Austenite during Controlled Rolling of Nb-containing Low-carbon Steel"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 32-37,31

TEXT OF ENGLISH ABSTRACT: An investigation was made of the effect of Nb on the retardation of recrystallization of austenite and refinement of ferrite grain size in hot-rolled Nb-containing low-carbon steels. Experiments of hot-rolling by one-pass were performed using seven kinds of vacuum-melted steels with various C and Nb contents. The main results obtained are as follows:
1) The retardation of recrystallization of austenite during the hot-rolling process in these steels is due mainly to Nb (C, N) content which has been in solution at soaking temperatures and finely precipitated in γ matrix during hot-rolling. Therefore, it must be noted that only those Nb contents which may form the Nb (C, N) precipitate, rather than all of the added Nb contents, play the role of retarding the austenite recrystallization during the hot-rolling process.
2) C contents in the steels during cooling, deformation and after deformation have little effect on the speed of Nb (C, N), but with increased Nb contents the speed of precipitation of Nb (C, N) also increased.
3) With the increase of the amount of precipitated Nb (C, N), the critical reduction

[Continuation of GANGTIE No 1, 1982 pp 32-37, 31)

of the recrystallization of austenite grains during deformation is also increased. This effect is more pronounced in the case of partial recrystallization than complete recrystallization of the γ grains after deformation.
4) When γ grain after deformation is not in a state of recrystallization, the average grain size of ferrite after transformation is dependent on the size of the affected austenite grain interface area.

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TITLE: "Study of Incomplete Fill at the Side of the Inner Flang-faces of the Web-cutting Open Rolling Pass"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 38-42

TEXT OF ENGLISH ABSTRACT: We put forward a concept concerning the "angle of spread-pulling down." On the basis of analyzing and processing the experimental data the influence of various factors on the angle value is discussed. The regressive equation for estimating the "angle of spread-pulling down" was established by using a regression and orthogonal design method. The relationship between the "angle of spread-pulling down" and the angle of the web-cutting element may be used to evaluate the degree of fill in the flanges, and to control the degree of "non-fill" in the flanges. The results from our original and follow-up experiments show that some conclusions in this paper are correct.

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TITLE: "Research on the Effect of Oil-saving and Reducing NO_x and Oil Coke Particles on Burning Emulsified Heavy Oil"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 43-50

TEXT OF ENGLISH ABSTRACT: There are different versions of the oil-saving effect by burning emulsified oil and the the data of the effect on reducing air pollution being deficient in China. The two problems mentioned above and the mechanism of combustion are studied. It is shown that by burning emulsified heavy oil the coefficient of excess air may be decreased to 1.02 - 1.05 in industrial furnaces and the results in saving oil are about 3.4 - 10 percent. When care is not taken to control the coefficient of excess air, an opposite result may be obtained. In addition, the effect of reducing the NO_x and oil coke particles is obvious. The amount of NO_x is reduced by 40 percent, and that of oil coke is reduced by 60 percent. The structure of oil coke obtained by burning of unemulsified heavy oil is that of carbonceous residues; that by burning emulsified heavy oil is fine particles which is most like tarry gas phase deposit. This result is consistent with the result obtained from laboratory experiments of single oil droplet burning. The size

[Continuation of GANGTIE No 1, 1982 pp 43-50]

of droplets and the stability of emulsified heavy oil prepared by mechanical stirring may be satisfied with the demand of test and production.

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TITLE: "Investigation of the Embrittlement Due to Slow Cooling in High Temperature Range in 18Ni Maraging Steel"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 51-57, 62

TEXT OF ENGLISH ABSTRACT: Many investigators have studied the embrittlement due to slow cooling in the high temperature range in 18Ni maraging steel. It is generally believed that the embrittlement is related to the precipitation of TiC and Ti (C, N) on prior austenite grain boundaries. We have systematically investigated the regularities, behavior and causes of the embrittlement and have obtained results different from those obtained by our predecessors. The main results are as follows: after high-temperature annealing (1200°C, 1 hr), and in intermediate isothermal holding at the most sensitive temperature (950°C), lots of M_3B_2 clusters precipitate on prior austenite grain boundaries and form a network thereon. It is the precipitates that cause the embrittlement of the steel. Moreover, ways to control and eliminate the embrittlement are also researched.

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ORG: All of the Central Iron and Steel Research Institute

TITLE: "The Application of Fracture Physics Parameter σ_f^* in Controlled Rolling"

SOURCE: Beijing GANGTIE [IRON AND STEEL] in Chinese No 1, 1982 pp 58-62

TEXT OF ENGLISH ABSTRACT: The micromechanism for improving the mechanical properties of steel by controlled rolling is investigated based on the physics of cleavage fracture.

According to the physical model of cleavage fracture of 16Mn steel and the experimental results of controlled rolling, the idea of alloy design by lowering the carbon content and decreasing the grain size in order to improve the strength and fracture properties was discussed. Along this line micro-alloy steel 05MnMoNb for controlled rolling was designed and investigated. Experimental results show that the steel satisfies successfully the requirements of X70 grade line pipe steels.

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CSO: 4009/265

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TITLE: "Determination of the Configurations of Flow Ellipsoids at the Mine"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 1-6, 80

TEXT OF ENGLISH ABSTRACT: Determination of the configuration of flow ellipsoids at the mine is an important link between scientific research and production practics in ore flow. The aim is to reduce ore loss and dilution during the process of ore flow. The main contents of this paper are: description of the method of encircling primarily the flow ellipsoids pattern, method of checking the pattern, the necessity of plotting curves showing the relationship between parameters of the adopted flow ellipsoids and their volumes, derivation of a formula for calculating the volume of the flow ellipsoids and discussion of the similarity of the connecting line of the top points of the flow ellipsoids to a parabola.

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TITLE: "Effect of Blasting Vibrations on Rock Slopes"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 8-13

TEXT OF ENGLISH ABSTRACT: The rock slope of an open pit is substantially a part of the mountain body and is a semi-infinite medium which consists of the same material as the gound. From this viewpoint, the paper describes how vibration waves are transmitted through the rock slope and how the stress field is distributed on rock slopes. It deals with the dynamic property of rock masses and the method of defining the safe charge weight.

The paper gives examples of calculation of how blasting vibration influences the stability of the rock slope.

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TITLE: "Analysis and Calculations of the Stress State and Efficiency of Impact Penetration System"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 15-22

TEXT OF ENGLISH ABSTRACT: In this paper, the Hertz theory of contact stress is introduced for the theoretical study of impact penetration, and a nonlinear theoretical model founded on the assumption that local deformations are yielded on both impact surfaces of bars is also proposed.

Based on the literature and the differential theorem, a calculating method using a digital computer for analyzing and calculating the stress state and efficiency of impact penetration system is established in a systematic way. A computer program for any system composed of a one-three segmental piston and a one-three segmental rod and/or bit has been designed. The mechanic parameters, the shapes of impact wave on any section and the efficiency of various impact penetration systems can be obtained by changing the values of input variables.

For verifying the theory presented in this paper, the stress state and efficiency of the impact penetration system of the down-hole drill is researched by combing

[Continuation of YOUSE JINSHU No 1, 1982 pp 15-22]

the calculating method of the computer with model experiments. The theoretical wave shapes of stress plotted by calculating with the digital computer tally quite well with the experimental wave shapes.

AUTHOR: LIU Chuanlin [0491 0278 7792]

ORG: Sanhe Lead and Zinc Mine, Guangxi

TITLE: "Separating Copper-Lead Concentrate by Flotation with Sodium Pyrophosphate"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 38-42

TEXT OF ENGLISH ABSTRACT: The new technology of separating bulk copper-lead concentrate with cyanide-free and bichromate-free reagents tested in the past two years has shown that sodium pyrophosphate, especially in combination with carboxymethyl cellulose (CMC), as a selective depressant of galena could produce satisfactory separation performance. For instance, separation of bulk copper-lead concentrate assaying about 64 percent Pb and 4.4 percent Cu with the above-mentioned reagents in flotation yielded a copper concentrate containing 27.65 percent Cu and 2.2 percent Pb with copper recovery of 96 percent, and a lead concentrate containing 75 percent Pb and 0.208 percent Cu with lead recovery of 99.47 percent.

Tests have also shown that the consumption of sodium pyrophosphate, its ratio to CMC and the consumption of this mixture, the type of CMC, the reagent conditioning time and other factors all had important effects on the bulk Cu-Pb concentrate separation by flotation.

[Continuation of YOUSE JINSHU No 1, 1982 pp 38-42]

Experiments on varied reagent systems for separating Cu-Pb concentrate indicated that sodium pyrophosphate, especially in combination with CMC, provided better results than those with CMC or bichromate. As a result, this new process, confirmed by experiments, has been adopted in mill practice.

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TITLE: "Study of the Magnetic Field Characteristics of Magnetized Ferromagnetic Wires and Their Technical Parameters"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 43-50

TEXT OF ENGLISH ABSTRACT: A short review of the magnetic field characteristics of magnetized ferromagnetic wires used in the high gradient magnetic separator and of the existing problems is given.

Based on the similarity principle, magnetic simulation is used for the systematic study of the magnetic field of magnetized ferromagnetic wires. The study includes: the effect of the material and the form of the cross section and dimension of the ferromagnetic wire on the magnetic force of the magnetized field, and the field distribution of the wire array. By means of mathematic treatment and calculation, parameters of ferromagnetic wire with round and oblong cross sections are optimized. These parameters can be of use in ore testing and in practice.

Results derived from theoretical consideration are confirmed by experiments on ore separation.

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TITLE: "The Flocculation Characteristics of Ilmenite and Feldspar"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 51-58

TEXT OF ENGLISH ABSTRACT: This paper describes in detail an investigation of selective flocculation of ilmenite from ilmenite-feldspar mixtures using a partially hydrolyzed polyacrylamide flocculant and a modified polyacrylamide possessing hydrozimic acid functional groups. It has been found that the lattice impurities and surface conditions of feldspar and the ion constituents of suspension have remarkable effects on the flocculation behavior of minerals and the selectivity of the process. The unfavorable effects as mentioned above can be decreased or eliminated after adding some auxiliary reagents or treating the feldspar with hydrochloric acid, thus improving the selectivity of the process.

The flocculation selectivity can be improved significantly by combining the flocculant with oxidized paraffin soap. An ilmenite concentrate with a grade of 47.05 percent TiO_2 and recovery of 84.9 percent is obtained from a mixture of

[Continuation of YOUSE JINSHU No 1, 1982 pp 51-58]

ilmenite and feldspar containing 25.06 percent TiO_2. Another ilmenite concentrate obtained from a mixture of ilmenite and acid-leached feldspar is 48.14 percent TiO_2 in grade and 88.7 percent in recovery, respectively.

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ORG: Northeast Institute of Technology

TITLE: "The Regularity of Decrease of Trace Metal Concentration in Aluminum during Determination of Current Efficiency in Aluminum Electrolysis by Dilution Technique"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 59-64

TEXT OF ENGLISH ABSTRACT: In the present work the regularity of decrease of trace metal concentration in liquid aluminum cathode in industrial aluminum cells was discussed. Theoretical formulas were derived.

General:

$$a_{n-(n+1)}(t)=\frac{C_0\prod_{i=0}^{n}\left(M_0+\bar{q}t_i-\sum_{j=0}^{i}m_j\right)}{\left(M_0+\bar{q}t-\sum_{j=0}^{n}m_j\right)\prod_{i=0}^{n}\left(M_0+\bar{q}t_i-\sum_{j=0}^{i-1}m_j\right)} \quad (1)$$

Simplified 1:

$$a_{n-(n+1)}(t)=\frac{C_0}{M_0+\bar{q}(t-t_n)}\left(\frac{M_0}{M_0+\bar{q}t_n}\right)^n \quad (2)$$

Simplified 2:

$$a_{n-(n+1)}(t_n)=a_0k^n \quad (3)$$

[Continuation of YOUSE JINSHU No 1, 1982 pp 59-64]

where

$$k = M_0/(M_0 + \bar{q}t_c)$$

When compared with practical data they are in good agreement.

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ORG: Guizhou Aluminum Plant

TITLE: "Determination of the α-Al_2O_3 Content in the Alumina Roasting Product by the 'True Specific Gravity Method'"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 65-70

TEXT OF ENGLISH ABSTRACT: Based on the phase analysis, this paper searches deeply into the phase form of alumina at various temperatures and its transformation law, ascertaining the phase composition of the alumina roasting product so that the theoretical foundation is established for a new method for the quantitative analysis of α-Al_2O_3 in the alumina roasting product--the "True Specific Gravity Method." Moreover, the reliability and sensitivity of the "True Specific Gravity Method" are shown in this paper and the results from the testing of the new method are compared with those from the "Diffractometer Method." The comparison shows that there are no apparent differences between the accuracy (or reliability) and reproducibility (or stability) in determining data of the two methods. Furthermore, the "True Specific Gravity Method" has the following advantages: 1) The specimen amount for producing data is dozens of times more than that of the "Diffractometer Method," so the representativensss of the results from the "True Specific Gravity Method" for the whole roasting product is much better; 2) The results can be obtained in two to three hours and used to analyze the production situation and to guide the

[Continuation of YOUSE JINSHU No 1, 1982 pp 65-70]

production or experiment just in time; 3) There is no harm from X-rays and the labor conditions are good; 4) There is no need for expensive precision instruments or for a particular working environment, so the method suits one's convenience quite well.

The sensitivity of the "True Specific Gravity Method" is 2 percent. This level is slightly lower than that of the "Diffractometer Method," but is quite enough to satisfy the requirements of production for α-Al_2O_3 quantitative analysis.

AUTHOR: XIA Guangxiang [1115 0342 4382]

ORG: Institute of Chemical Metallurgy, Chinese Academy of Sciences

TITLE: "Extracting Copper from Ammoniacal Solutions by Lignite Adsorption Technique"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 71-76, 58

TEXT OF ENGLISH ABSTRACT: Adsorption of copper in ammoniacal solutions by means of lignite and its stripping was investigated. The factors affecting these operations were also discussed. It is shown that the concentration of copper in the depleted solution was below 1 ppm, and the maximum loading with all three specimens, i.e., copper, ammonia and carbon dioxide, is 0.30 grams per gram lignite, and the mole ratio of those specimens on the lignite is generally 1:6:2 ($Cu:NH_3:CO_2$). When the loaded lignite was stripped with sulfuric acid, the ammonia on it was first desorbed and the mole ratio of the remaining copper to the ammonia gradually increased from 1:4 to 1:2 until the stripping was completed. According to research results the lignite adsorption technique may be applicable to the following steps of the ammonia extracting copper process: preventing the formation of hard cake during distillation of ammoniacal copper solutions; recovering copper and ammonia from both dilute solutions obtained in solid-liquid separation and waste effluent containing sulfate radical. The technique is especially suited to the reduction roasting-ammoniacal leaching process for extracting copper.

AUTHOR: LI Zhongjun [2621 0112 0971]

ORG: Research Institute of Natural Science History, Chinese Academy of Sciences

TITLE: "Gold Mining in Ancient China"

SOURCE: Beijing YOUSE JINSHU [NONFERROUS METALS] in Chinese No 1, 1982 pp 78-80

TEXT OF ENGLISH ABSTRACT: The gold production in ancient China is reviewed in this article, based on existing literal records. Gold ores mined in ancient times were divided into placer gold and "hill gold." The placer gold, or "water gold," was mostly obtained from elutriation of river- or lake-bed sands, with some excavated from shafts, while the "hill gold" was mostly recovered from eluvial and hill slope placers, earlier gold placers and vein deposits. Gravity separation was the primary process for gold ore beneficiation in the early times.

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